Technical Report 859

Development of a Unit-Conduct of Fire Trainer (U-COFT) Test of M1 Gunnery Proficiency

R. Gene Hoffman
Human Resources Research Organization

Bob G. Witmer
U.S. Army Research Institute

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EDGAR M. JOHNSON
Technical Director

JON W. BLADES
COL, IN
Commanding

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Technical review by

Scott E. Graham
Millicent H. Abel

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A test of M1 gunnery proficiency based on content analysis of Tank Table VIII engagement parameters was prepared for the Unit-Conduct of Fire Trainer (U-COFT). The test is composed of four U-COFT exercises comprising 23 different moving (offensive) and stationary (defensive) engagements against both moving and stationary, single and multiple targets. Special instructions were developed for U-COFT Instructors/Operators. Hit rate was identified as the most appropriate composite measure of gunnery performance. Instructions were prepared for calculating hit rate for each engagement in the test and for calculating hit rate for the test as a whole. Additional measures were identified for supplementary analyses of performance. These include firing rate, hit probability, average opening time, average miss distance, and average numbers of classification and system management errors. Use of this test should facilitate our ability to integrate research in tank gunnery and thereby increase our understanding of performance requirements in tank gunnery.

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R. Gene Hoffman
Human Resources Research Organization

Bob G. Witmer
U.S. Army Research Institute

Field Unit at Fort Knox, Kentucky
Donald F. Haggard, Chief

Training Research Laboratory
Jack H. Hiller, Director

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

Office, Deputy Chief of Staff for Personnel
Department of the Army

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FOREWORD

Tank crew gunnery proficiency is assessed on Tank Table VIII, a series of live-fire engagements difficult to standardize from one administration to another and expensive to administer. An alternative to this approach is to assess gunnery skills on the Unit-Conduct of Fire Trainer (U-COFT). The use of this device would facilitate the standardization of test conditions and reduce testing costs.

This report describes the development of an M1 gunnery proficiency test for tank commanders and gunners to be administered on the M1 U-COFT. The test was constructed to sample the gunnery conditions represented on Tank Table VIII. The report also contains a handbook describing the administration and scoring of the test.

In addition to its role in Army training, U-COFT has been an important tool in Army-sponsored research, including research conducted by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI). Issues investigated using U-COFT have focused on individual differences as predictors of performance and on the effects of training and experience on performance. The research has been inconsistent in the U-COFT exercises selected for criterion measurement, and has hampered comparisons and synthesis of research results. A standardized test of gunnery proficiency administered on U-COFT would provide a low-cost instrument that would facilitate the integration of future research efforts using U-COFT.

This research is part of the ARI task entitled "Application of Technologies to Meet Armor Skills Training Needs." This task is performed under the auspices of ARI's Armor Research and Development Activity at Fort Knox. The mission of the task is to design and conduct human performance research in armor gunnery. The report was delivered to the Acting Director of the Directorate of Evaluation and Standardization at Fort Knox and to the III Corps G3, Training, at Fort Hood. The assessment methodology and the test items have been used to establish criteria for two projects conducted for the U.S. Army Armor Center (USAARMC) and Training and Doctrine Command (TRADOC). These projects examined the change in gunnery skills during transition training on M1 U-COFT and the effects of mental rehearsal on gunnery skill acquisition.

TRADOC is the proponent for this research, and USAARMC is the user (Memorandum of Agreement with ARI entitled "The Effects of Simulators and Other Resources on Training Readiness," 16 January 1989).

EDGAR M. JOHNSON
Technical Director

DEVELOPMENT OF A UNIT-CONDUCT OF FIRE TRAINER (U-COFT) TEST OF M1 GUNNERY PROFICIENCY

EXECUTIVE SUMMARY

Research Requirement:

This report describes in detail the construction of a standardized test of M1 gunnery proficiency for tank commanders and gunners using the M1 Unit-Conduct of Fire Trainer (U-COFT). The test provides a standardized research tool for integrating future research efforts in M1 tank gunnery.

Procedure:

Preparation of the test included four activities. First was selection of U-COFT exercises to represent the domain of conditions defined by M1 Tank Table VIII. Second was detailing administration procedures and composing a test administrator's script. The third activity was preparing a test administrator's orientation guide outlining general dos and don'ts of performance testing. The final activity was selecting performance measures and writing scoring instructions.

Findings:

The U-COFT test is composed of four U-COFT exercises comprising 23 different moving (offensive) and stationary (defensive) engagements against both moving and stationary, and single and multiple targets. Special instructions were developed for U-COFT Instructor/Operators to follow instead of using their routine U-COFT training procedures. Hit rate was identified as the most appropriate composite measure of gunnery performance. Instructions were prepared for calculating hit rate for each engagement in the test and for calculating hit rate for the test as a whole. Additional measures were identified for supplementary analyses of performance. These include firing rate, hit probability, average opening time, average miss distance, and average numbers of classification and system management errors.

Utilization of Findings:

Use of this test in future tank gunnery research projects should facilitate our ability to integrate research in tank gunnery and thereby increase our understanding of performance requirements in tank gunnery. For example, this test could be used in studies of training progress on U-COFT, in studies attempting to predict crew performance on other gunnery exercises such as Tank Table VIII, or in studies comparing the effects of alternative training strategies on crew gunnery performance.

DEVELOPMENT OF A UNIT-CONDUCT OF FIRE TRAINER (U-COFT) TEST OF M1 GUNNERY PROFICIENCY

CONTENTS

LIST OF TABLES

LIST OF FIGURES

DEVELOPMENT OF A UNIT-CONDUCT OF FIRE TRAINER (U-COFT) TEST OF M1 GUNNERY PROFICIENCY

This report describes the development of a standardized procedure using the M1 Unit-Conduct of Fire Trainer (U-COFT) to test the skills of M1 tank commanders and gunners. The first section describes the construction of the U-COFT M1 gunnery skills test. It presents constraints for test administration, the rationale for the selection of the engagements used in testing, general considerations for test administration, and caveats concerning the use of performance measures. It also describes test administration procedures, including sections about training U-COFT instructor/operators (I/O) to administer the test and about test administration procedures. The second section discusses issues and problems related to the scoring of gunnery in general and the U-COFT test in particular. U-COFT I/O training information, the test administration procedure, and the scoring procedure are presented in a separate Handbook which is presented in Appendix A.

Test Construction

Testing Constraints

This test was designed to meet several constraints. First, the time available for testing each crew[1] was limited to one hour. Since some time would be required to brief the crew, this allows only four U-COFT exercises to be administered. Second, the test procedures should require only one U-COFT I/O. Without additional help, that person cannot be expected to record performance data. Therefore, U-COFT printouts could be the only source of performance measures. This, in effect, limits the use of the test to general comparisons between crews, with only limited diagnoses of selected performance problems. Finally, only complete U-COFT exercises could be used since partial exercises are hard to run on U-COFT and lead to administration errors (Graham, 1986). Finally, the test would be administered only to personnel who are already familiar with U-COFT.

Purpose of the Test

The primary purpose of this test is to provide a standardized method for assessing a crew's gunnery proficiency on U-COFT. U-COFT provides three different printouts with a variety of crew performance indicators. Selection and scoring of these indicators can be tailored to particular research questions. Indeed, a number of research efforts have already used U-COFT to assess crew proficiency (Abel, 1987; Black & Abel, 1987; DuBois, 1987; Graham, 1986; Smith & Graham, 1987; Witmer, 1988a, 1988b). The exercises and scoring varied across these studies. Advancing the understanding of tank gunnery

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[1]We use the term "crew" throughout this report even though U-COFT is configured to train TC and gunner only. "Crew" should be understood to refer only to the TC and the gunner.

skill acquisition and performance measurement is a reiterative process. Any one study cannot answer all questions. While each study may use performance measures of particular interest, it is also important to have a set of standardized scoring procedures that can be used to tie together the results and conclusions of these studies. Furthermore, if a single summary measure could be identified to rank tank crews, the process of drawing simple, straight forward conclusions from any one study or across studies would be greatly facilitated (Witmer, 1986). If future research supports their validity, U-COFT proficiency scores could be used for such purposes as evaluating progress in U-COFT training, predicting crew performance on Table VIII, predicting crew contributions to company tactical missions, or comparing crew scores in various research experiments.

Limited Application

Until the issues of reliability, validity and norming are addressed, use of this test should be limited to research applications only. The scoring procedures that are presented below are cumbersome and are not practical for routine use by units in on-going training. Those who do conduct research with this set of exercises are encouraged to share their data with the ARI-Field Unit, Ft. Knox, Ky.

Rationale for Selecting U-COFT Gunnery Exercises

Constructing a proficiency test of any kind requires a precise definition of the domain to be tested. Test items are then sampled from that domain. Initially the domain for the U-COFT test was to be defined by the tasks included in Tank Gunnery Table VIII. Table VIII is the culminating individual tank exercise in the series of tank exercises presented in FM 17-12-1. It is the exercise used to qualify tank crews. Table VIII requires tank crews to fire ten engagements consisting of one or two targets each, including both day and night engagements. FM 17-12-1 specifies twelve different engagements. Two alternate tasks are included, one day engagement for ranges with only one moving target, and one night engagement for use when illumination is not available. The intent of Table VIII is for crews to fire five day and five night engagements. However, two tasks, one day and one night, are designated as swing tasks to be fired either day or night to accommodate daylight availability. Thus, each crew fires ten engagements, but not all crews fire the same ten. Counting the swing tasks twice (as day engagements and as night engagements), there are 14 tasks specified by Table VIII.

FC 17-12-7-1 (M1 Unit-Conduct of Fire Training Device Support Package) gives a crosswalk between twelve of the Table VIII tasks and the U-COFT exercises (each of the two swing tasks are only referenced once). There are no matching U-COFT exercises for Table VIII tasks A2, A3, B3, B4 and B5. The match is only approximate for A1, A5-Day, A5-Night, and B2. The only tasks that are replicated by U-COFT are A4, A5A, B1-Day, B1-Night and B5A. Furthermore, these five Table VIII matches appear in five different U-COFT exercises. Thus, if the Table VIII tasks were used as the gunnery domain to be tested by U-COFT, only five of the fourteen tasks could be covered, and they would require running five different U-COFT exercises.

Because of the few number of Table VIII tasks that could be represented on U-COFT, an alternative domain definition and item selection strategy was used to construct the U-COFT test. Instead of matching Table VIII tasks, the conditions that define those tasks were identified and test engagements were selected to match those conditions. U-COFT exercises were selected to cover target arrays, ranges, firing tank movement, target movement, NBC, crew configuration (four- or three-man), day/night and number of targets per engagement as found in Table VIII. Although the specific combinations of these conditions could not be selected to replicate all Table VIII tasks, U-COFT exercises could be selected to cover all of the conditions in combinations somewhat different from the tasks. Where possible, additional conditions were included in the composition of the test.

U-COFT exercises are organized in increasing difficulty in a training matrix which has six major groups of exercises. The exercises differ in movement of the firing tank and movement of the targets.[2] The exercises that contain the greatest variety of engagements, and therefore cover the greatest number of conditions, are those in Group 6 of the U-COFT matrix. Exercises 34633 and 34611 were selected from this group to provide moving and stationary firing tank exercises against multiple moving and stationary targets. These exercises are described in Tables 1 and 2.

The engagements in exercise 34633 (Table 1) are from a moving tank with tank, helicopter, troop and APC targets. This exercise is under U-COFT battlefield conditions which include a friendly M1 appearing in one engagement, firing from other vehicles depicted in the scene, and visibility reduced by fog. FM 17-12-1 suggests the optional placement of friendly tanks within the target array. The fog condition simulates the kind of visibility problems under which alternating use of GPS and TIS is effective. This exercise has two replications with different sets of targets. Replication 1 was chosen because it includes retreating targets, a condition that would not otherwise be covered.

Exercise 34611 (Table 2) includes four multiple target engagements, all fired from a stationary tank in daylight with unlimited visibility. Engagement 1 is a simultaneous engagement with the TC engaging troops and the gunner engaging a threat tank. The remaining engagements contain tank targets and one helicopter. Target ranges in this exercise are longer than Table VIII, but for U-COFT's day, unlimited visibility targets, the only visual effect of range is to reduce the apparent size of the target. Factors related to range which affect visual acuity are not present in U-COFT, so that 2000-meter U-COFT targets are not as hard to see as actual 2000-meter targets (see Hoffman and Morrison, 1988). The four engagements in this exercise can be

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[2]U-COFT matrix groups 1 and 2 present stationary own vehicle and stationary targets; group 3 is stationary own vehicle with moving targets; group 4 is moving own vehicle with stationary targets; group 5 is moving own vehicle with moving targets; and finally, group 6 contains stationary and moving own vehicle engagements against stationary and moving targets. The order of progression for training under the revised programming is group 1, 2, 4, 3, 5 and 6.

Table 1

U-COFT Exercise 346331 - Moving Own Tank, Day, Multiple Moving and Stationary Targets, Battlefield Conditions

Engagement Presentation Sequence	Firing Tank Speed	Targets	Range	Target Motion Speed	View	Gun	Sight	Ammo
1	25 MPH	Tank	1710	Stationary	Full 45° Left	Main	GPS	SABOT
		Heli-copter	1850	Stationary	Full Front	Main	GPS	HEAT
2	35 MPH	Tank	1390	Stationary	Full 45° Right	Main	GPS	SABOT
		Troops	890	Stationary	Full Front	Coax	GPS	7.62mm
3	25 MPH	Tank	1600	Moving 25 MPH	Full 45° (Right Away)	Main	GPS	SABOT
		APC	1840	Moving 25 MPH	Full 45° (Left Away)	Main	GPS	HEAT
4	25 MPH	Tank	1820	Stationary	Full Right	Main	GPS	SABOT
		M1 Tank	1750	Moving 25 MPH	Full Right	N/A	GPS	N/A[a]
5	30 MPH	Tank	1770	Stationary	Full 45° Left	Main	GPS	SABOT
		Heli-copter	1380	Moving 35 MPH	Full Right	Main	GPS	HEAT[b]

[a]Friendly vehicles should not be engaged.

[b]The initial programming of U-COFT required that helicopters be engaged with HEAT in second and subsequent rounds in order to avoid an ammunition selection error. However, SABOT is correct by doctrine, and recent U-COFT programming reflects this. For this test, SABOT is the correct ammunition for helicopters regardless of which version of U-COFT programming is used. If a U-COFT with the initial programming is used, ammunition selection errors caused by the crew using SABOT are to be ignored.

Table 2

U-COFT Exercise 346110 - Stationary Own Tank, Day, Multiple Moving and Stationary Targets

Engagement Presentation Sequence	Firing Tank Speed	Targets	Range	Target Motion Speed	View	Gun	Sight	Ammo
1	Stationary	Tank	2100	Stationary	Full 45° Left	Main	GPS	SABOT
		Troops	1090	Stationary	Full Front	Main	Cal .50	Cal .50
2[a]	Stationary	Tank	1670	Stationary	Full Front	Main	GPS	SABOT
		Tank	1690	Stationary	Full 45° Left	Main	GPS	SABOT
		Tank	1930	Stationary	Full 45° Right	Main	GPS	SABOT
3[b]	Stationary	Tank	1730	Stationary	Full Right	Main	GPS	SABOT
		Tank	1980	Stationary	Full 45° Left	Main	GPS	SABOT
		Tank	2020	Moving 20 MPH	Full Front	Main	GPS	SABOT
4	Stationary	Tank	1870	Moving 32 MPH	Full Left	Main	GPS	SABOT
		Heli-copter	1920	Moving 27 MPH	Full 45° Right	Main	GPS	SABOT[c]

[a]Crews don protective masks for NBC engagement.

[b]Crews fire a three-man (TC only) engagement.

[c]See Note b on previous page.

presented in four different sequences. In the absence of information about order effects, the test specifies that all crews are to be given the engagements in the same sequence. Replication 0 was chosen, arbitrarily.

These two exercises do not cover the Table VIII conditions of firing under NBC conditions, firing with a three-man crew, GAS gunnery and night gunnery. To cover NBC and three-man crew engagements (where the TC fires the main gun), we modified exercise 34611 (Table 2) to require use of protective masks for the second engagement and to have the TC fire the third engagement without the gunner's assistance.

Exercise 34622, also from Group 6, was chosen to cover night gunnery. This exercise is fired from a stationary tank at multiple, moving and stationary tanks, APC and helicopter targets. For additional coverage of NBC and three-man crew conditions, one engagement was modified to require use of protective masks, and one engagement was modified to require the TC to fire the main gun without the gunner. This exercise also has four possible orders, each with the same four engagements. Replication 0 was chosen for presentation to all crews. This exercise is shown in Table 3.

Table VIII also specifies a task that requires engaging both stationary and moving targets from a stationary (defensive position) tank using the gunner's auxiliary sight (GAS). None of the Group 6 exercises include GAS gunnery. Outside of U-COFT Group 6, no GAS exercises include both stationary and moving targets. Instead of simply attempting to match the Table VIII task as closely as possible, consideration was also given to conditions not covered in the first three exercises. Thus, the GAS gunnery exercises were selected from Group 5 with moving own tank and moving targets. Moving own tank was substituted for stationary own tank in order to include the technique of firing from a short halt. Exercise 31563 was selected as the final exercise. It is described in Table 4. There are two distinct target arrays for the exercise; replication 1 was chosen because it includes a full frontal target.

Table 5 illustrates the conditions covered by these four exercises. The list of conditions was derived by Hoffman and Morrison (1988). The conditions included in defining Table VIII tasks are highlighted with bold print. All of the conditions included in defining the Table VIII tasks are covered by these four U-COFT exercises.

Test Standardization and General Administration Issues

For any set of test scores to be interpretable, testing conditions must be standard for all test takers. There are several implications of this basic tenet of testing.

The first implication is that during the test crews can be given no coaching or feedback about their performance (other than what they see in their sights). To do so creates a different set of test conditions for those crews that receive negative feedback compared to those that receive positive feedback. This differential treatment can change the skills of the crews even while they are being tested. Testing assumes that at a particular point in

Table 3

U-COFT Exercise 346220 - Stationary Own Tank, Night, Multiple Moving and Stationary Targets

Engagement Presentation Sequence	Firing Tank Speed	Targets	Range	Target Motion Speed	View	Gun	Sight	Ammo
1	Stationary	Tank	1820	Stationary	Full Front	Main	GPS (TIS)	SABOT
		Tank	1980	Stationary	Full 45° Left	Main	GPS (TIS)	SABOT
2	Stationary	Tank	1650	Stationary	Full Front	Main	GPS (TIS)	SABOT
		Tank	1680	Stationary	Full 45° Left	Main	GPS (TIS)	SABOT
		Tank[a]	1960	Stationary	Full Right	Main	GPS (TIS)	SABOT
3[b]	Stationary	Tank	1700	Moving 23 MPH	Full Right	Main	GPS (TIS)	SABOT
		Heli-copter	1830	Moving 28 MPH	Full 45° Right	Main	GPS (TIS)	HEAT[c]
		APC	1820	Moving 15 MPH	Full 45° Right	Main	GPS (TIS)	HEAT
4[d]	Stationary	Tank	1830	Moving 18 MPH	Full 45° Left	Main	GPS (TIS)	SABOT
		Tank	1970	Moving 21 MPH	Full Front Variable	Main	GPS (TIS)	SABOT

[a]This target is listed in the U-COFT manual as a M2/3. It appears in the exercise as a T72.

[b]Have crew don protective masks for NBC engagement.

[c]See note b for Table 1.

[d]Instruct crew to fire a three-man (TC only) engagement.

Table 4

U-COFT Exercise 315631 - Moving Own Tank, Day, Single Moving Targets, GAS Required

Engagement Presentation Sequence	Firing Tank Speed	Targets	Range	Target Motion Speed	View	Gun	Sight	Ammo
1	15 MPH	Tank	1060	Moving 15 MPH	Full Front	Main	GAS	SABOT
2	15 MPH	Tank	1170	Moving 15 MPH	Full Left	Main	GAS	SABOT
3	10 MPH	APC	990	Moving 10 MPH	Full 45° Left	Main	GAS	HEAT
4	10 MPH	Tank	1430	Moving 15 MPH	Full Right	Main	GAS	SABOT
5	10 MPH	M60A3 Tank	880	Moving 10 MPH	Full Left	N/A	GAS	N/A
6	15 MPH	Truck	1080	Moving 15 MPH	Full Right	Main	GAS	HEAT
7	10 MPH	APC	950	Moving 10 MPH	Full 45° Left	Main	GAS	HEAT
8	15 MPH	Tank	1380	Moving 10 MPH	Full 45° Left	Main	GAS	SABOT
9	10 MPH	Truck	510	Moving 15 MPH	Full Left	Coax	GAS	7.62mm
10	15 MPH	Tank	1310	Moving 15 MPH	Full 45° Left	Main	GAS	SABOT

Table 5

U-COFT Coverage of M1 Gunnery Conditions

Conditions	Levels	Exercise 346331	346110	346220	315631	Total
1. Target Type	Main Gun					
	a. Tank	X	X	X	X	X
	b. Personnel carrier	X	0	X	X	X
	c. Helicopter	X	X	X	0	X
	d. Bunker	-	-	-	-	-
	e. Antitank	-	-	-	-	-
	f. Truck	0	0	0	X	X
	g. Troops (including machine-gun, anti-tank grenade launchers, and antitank grenade missile teams)	X	X	0	0	X
	h. Fixed wing, high performance aircraft	-	-	-	-	-
2. Target Movement	*Stationary*					
	a. Front	X	X	X	0	X
	b. Flank	0	X	0	0	X
	c. Oblique	X	X	X	0	X
	Moving					
	d. Flank	X	X	X	X	X
	e. Oblique	X	X	X	X	X
	f. Zigzag	-	-	-	-	-
	g. Approaching	-	X	X	X	X
	h. Retreating	X	0	0	0	X
3. Target Cover/ Concealment	a. Fully exposed	X	X	X	X	X
	b. Hull defilade	X	-	-	-	-
	c. Turret defilade	-	-	-	-	-
	d. Fully hidden	-	-	-	-	-
4. Target Array	a. Single targets in distinctly separate engagements	0	0	0	X	X
	b. Multiple targets in distinctly separate engagements	X	X	X	0	X
	c. Continuous, unpredictably appearing targets such that some appear individually and some appear with others	-	-	-	-	-

(table continues)

Conditions	Levels	Exercise 346331	346110	346220	315631	Total
5. Target Orientation	a. Threat weapons oriented on own tank	X	X	X	X	X
	b. Threat weapons oriented elsewhere	X	X	X	X	X
6. Target Range	a. Up to 900 (Coax tracer burnout)	X	0	0	X	X
	b. 900-1800 (Cal .50 maximum effective range)	X	X	X	X	X
	c. 1800 and over	X	X	X	0	X
7. Target sector	a. Forward	X	X	X	X	X
	b. Flanks	-	-	-	-	-
	c. Rear	-	-	-	-	-
8. IFFN (identify friend or foe nomenclature)	a. All threat	X	X	X	X	X
	b. All friendly	-	-	-	-	-
	c. Mix	X	0	0	X	X
9. Enemy Activity	a. No return fire	0	X	X	0	X
	b. Direct fire	X	0	0	X	X
	c. Indirect fire	-	-	-	-	-
	d. Obstacles	-	-	-	-	-
	e. Minefields	-	-	-	-	-
	f. Electronic counter-measures	-	-	-	-	-
10. NBC (nuclear) biological, chemical) conditions	a. MOPP Zero	X	X	X	X	X
	b. Mask Only	0	X[a]	X[a]	0	X
11. Equipment Status[b]	a. Fully operational	X	X	X	0	X
	b. GPS failure	0	0	0	X	X
	c. Lead angle failure	0	0	0	X	X
	d. TIS failure (night)	0	0	0	0	0
	e. Crosswind sensor failure	0	0	0	0	0
	f. Cant sensor failure	0	0	0	0	0
	g. Loss of symbology	0	0	0	0	0
	h. Stabilization failure	0	0	0	X	X
	i. LRF failure	0	0	0	0	0
	j. Turret power failure	0	0	0	0	0
	k. Computer failure	0	0	0	X	X
12. Number of Crewmen	a. Four	X	X	X	X	X
	b. Three	0	X[c]	X[c]	0	X

(table continues)

Conditions	Levels	Exercise				
		346331	346110	346220	315631	Total
13. Supply Shortages	a. Ammo	-	-	-	-	-
	b. Fuel	-	-	-	-	-
	c. Food	-	-	-	-	-
	d. Smoke grenades	-	-	-	-	-
	e. Other	-	-	-	-	-
	f. None	X	X	X	X	X
14. Mission	a. Moving offense	X	0	0	X	X
	b. Stationary defense	0	X	X	0	X
15. Fire Control	a. Single tank	X	X	X	X	X
	Section Control					
	b. Frontal	-	-	-	-	-
	c. Cross	-	-	-	-	-
	d. Depth	-	-	-	-	-
	Platoon Control					
	e. Frontal	-	-	-	-	-
	f. Cross	-	-	-	-	-
	g. Depth	-	-	-	-	-
16. Formation	a. Column	-	-	-	-	-
	b. Echelon left/right	-	-	-	-	-
	c. Staggered column	-	-	-	-	-
	d. Line	-	-	-	-	-
	e. Wedge	-	-	-	-	-
	f. Herringbone	-	-	-	-	-
	g. Vee	-	-	-	-	-
	h. Coil	-	-	-	-	-
	i. Combat column	-	-	-	-	-
17. Special engagement requirements	a. Surprise targets	X	X	X	X	X
	b. Assault fire	-	-	-	-	-
	c. Support by fire	-	-	-	-	-
	d. Fire and maneuver	-	-	-	-	-
	e. By-pass	-	-	-	-	-

(table continues)

Conditions	Levels	Exercise 346331	346110	346220	315631	Total
18. Space	*Offensive*					
	a. Support by fire position interval	-	-	-	-	-
	b. Fire and maneuver interval	-	-	-	-	-
	c. Assault interval	-	-	-	-	-
	Defense					
	d. Fire position interval	-	-	-	-	-
19. Visibility	*Day*					
	a. Unlimited	**0**	**X**	**0**	**0**	**X**
	b. Haze, smoke, rain, snow or fog	**X**	**0**	**0**	**X**	**X**
	Night					
	c. Without illumination	**0**	**0**	**X**	**0**	**X**
	d. With continuous illumination (e.g., fires, moon)	-	-	-	-	-
	e. With periodic illumination (e.g., flares)	-	-	-	-	-
20. Terrain Grade	a. Level	0	0	0	0	0
	b. Up slope	0	0	0	0	0
	c. Down slope	0	0	0	0	0
	d. Hilly	X	X	X	X	X
21. Terrain Vegetation	**a. None**	-	-	-	-	-
	b. Brush	X	X	X	X	X
	c. Trees - scattered	X	X	X	X	X
	d. Trees - dense woods	-	-	-	-	-
22. Cultural Features	**a. Rural**	**X**	**X**	**X**	**X**	**X**
	b. Villages/towns	-	-	-	-	-
	c. Suburban	-	-	-	-	-
	d. Urban	-	-	-	-	-

Notes: - = not possible on U-COFT.

X = covered by U-COFT test.

0 = possible on U-COFT, but not included in U-COFT test exercises.

Conditions in **BOLD** print are conditions used in defining Table VIII tasks.

[a]Modify instructions to provide NBC (Mask only) engagements (moving and stationary targets). See Tables 1 and 4.

[b]Failures on U-COFT are presented as combinations of failures, not as individual failures.

[c]Modify instruction to provide three-man crew. See Tables 2 and 3.

time crews have fairly stable levels of proficiency. Proficiency levels can change over time, but if they change dramatically during test administration, the meaning of a test score is doubtful. Feedback, even the naturally occurring feedback that comes from seeing targets hit or missed, can cue new responses and change crew proficiency level. Thus, with a one hour test that includes 38 targets, there are likely to be some learning effects occurring naturally. Such incidental learning cannot be controlled. On the other hand, except as noted below, no additional cues will be given that could facilitate learning during the test.[3]

Second, a standardized set of instructions is required that is tailored for testing conditions rather than the normal training conditions provided by U-COFT. The instructions should give only the information needed to begin the exercise. They should not contain cues on how to perform. For example, standardization requires that switch settings at the beginning of each exercise should be the same for all crews. The instructions, however, should not include information on the switches that will require changing in the course of the exercise. Thus, special instructions have been prepared for the test.

A particular problem for testing gunnery is that performance requires crews to manipulate their environment and change the stimuli they receive (e.g., the view from the GPS). In so doing, the conditions of the test are changed. Because different crews are not going to make the same manipulations, maintaining test standardization becomes a problem. Two particular aspects of this problem are the orientation of the gun tube and switch settings.

During a moving own tank exercise, if a gunner fails to release the palm switches while traveling between engagements, it is easy to inadvertently get the gun tube out of the target sector. Consequently, the crew may fail to detect subsequent target arrays. Scores on the missed target array would be the result of one procedural error, and they would give no information about the crew's marksmanship abilities. Our safeguard for this type of occurrence is to allow the I/O to assume the role of platoon leader or platoon sergeant, and for the I/O to ensure that crews maintain their orientation within the target sector. Although this violates standardization to the extent that not all crews will receive or need to receive the same instructions to maintain their orientation, it facilitates standardization by ensuring that all crews have a chance to engage every target array.

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[3]Whether feedback is given after the test is completed depends on the particular research project. In some cases, the research design may mandate that no feedback be given even after the test session is completed. In other cases, it may be allowable. From the viewpoint of the individual crew, it is beneficial to receive the feedback, and it may be frustrating for the crew to have it withheld.

As for the switch settings, perhaps the most problematic is the ammunition selection switch. In U-COFT, reticle aim is scored by the fall of the round rather than the lay of the gun. Thus, if a gunner fails to select the correct ammunition, no information can be gained regarding his tracking or aiming skills. It certainly would be desirable to obtain measures of both ammunition selection and tracking by having lay error calculated from reticle aim rather than from the fall of the round. In lieu of that, consideration was given to correcting incorrect settings as they happen. Obviously, this would involve giving feedback to crews that make such mistakes; the feedback, in turn, could facilitate their subsequent performance. More importantly, performance events happen much too rapidly for such interventions. Although some information will be lost, to maintain standardization and minimize feedback, instructions on switch setting will be given only at the start of each exercise. Even then, only sufficient information will be given to unfreeze U-COFT, allowing the exercise to continue. Given the configuration of U-COFT, it is not possible to obtain all of the information that is desired.[4]

Instructor/Operator Training

Although U-COFT is largely automated, its operation (and therefore the administration of the test) requires a qualified U-COFT instructor/operator. Because of the standardization requirements, procedures for administering the test are considerably different from procedures for normal training. Thus, adequate time and attention must be given to preparing an I/O to administer the test. Primarily this means (a) providing an overview of the purpose that highlights the difference between testing and training, (b) emphasizing the criticality of standardized procedures with no feedback, and (c) conducting adequate practice prior to actual administration. The accompanying handbook, in Appendix A, provides an orientation that should be given to each I/O. In addition to presenting this orientation, the researcher should describe the purpose of the research for which the test is being used.

Testing Procedures

Detailed instructions for administering the U-COFT test are in the handbook in Appendix A. The U-COFT I/O should practice administering the test exactly as it is described in those instructions. Practice should be conducted under the direction of the researcher. For example, the instructions specify a number of switch settings for the I/O to set prior to the arrival of the crew. The I/O should not deviate from those instructions by having the crew set the switches prior to the first engagement. Also, when reading instructions to the crew, the I/O should read exactly what is written. The I/O should not add or delete anything.

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[4]For example, a device for testing could be configured to record any errors that are made (e.g., incorrect ammunition selection, incorrect lasing), but to act as if the responses were correct in order to allow the uncontaminated measurement of subsequent responses.

The researcher should monitor test administration. Again, the I/O will be performing in ways that are sometimes inconsistent with the normal routine. Lapses back into that routine can occur.

Scoring U-COFT Test Performance

Because of the complexity of tank gunnery, there are two related considerations in constructing a scoring system: the purpose of the test and the selection of the metrics to use. Hoffman and Morrison (1988) discuss two basic purposes of performance testing. One purpose is to diagnose performance in order to determine where performance improvements need to be made and to facilitate feedback on how to make those improvements. The second purpose is to assess overall crew proficiency in order to predict differences in future performance or to assess the effects of different kinds of experience, such as a comparison of different training programs. A primary difference between the two purposes is in the kind and detail of the scoring procedures. For example, outcome measures (e.g., target hits) may be useful for proficiency assessment, but they provide very limited diagnostic information.

The diagnostic purpose is given a secondary emphasis in the construction of the U-COFT test. The constraint to use U-COFT printouts as the source of performance measures limits the availability of diagnostic information. Thus, the test cannot classify crews by all of the kinds of errors they may be making. For example, missing a target may result from incorrectly setting the ammo selection switch, from incorrectly lasing, from poor manipulation of the power control handles, or from a combination of these. Similarly, time scores are partially a function of several components, including slow responding and incorrect responding (e.g., forgetting to turn the main gun switch on), or violating safety standards (e.g., leaving the main gun switch on all of the time). Information on many of these individual factors is not provided by U-COFT printouts. The normal U-COFT training mode is very flexible and involves the I/O in the process of diagnosing and coaching crew problems. This mode for providing diagnostic feedback for improving performance is a much more appropriate strategy than using a standardized test. Therefore, the scoring procedures developed for U-COFT will focus on assessing overall gunnery proficiency.

Selecting an Overall Proficiency Score

Even if one could remove all the technical aspects of measurement (e.g., reliability problems), scoring tank gunnery does not easily lend itself to unequivocal measurement. Guion (1977) and Hambleton (1980) have warned that content sampling concerns are only one aspect of content validity. The other important aspect is the validity of the scoring procedures. In the case of scoring tank gunnery, this is not a trivial concern. This section contains an in-depth analysis of scoring gunnery proficiency for an individual tank crew.

Criterion tests of overall job proficiency are generally expected to provide a single score. Typically, multiple tasks or test items are

individually scored and combined to give a composite score. Witmer (1986) proposed a composite gunnery index based on a conceptual analysis of the behaviors per se inherent in gunnery with concern for the kinds of measures generally available on existing gunnery simulators. He combined speed (opening time) and accuracy indexes (percent of hits, percent of first round hits, and aiming error) with speed and accuracy weights adjusted for group norms. An alternative is to view a composite criterion score as an indication of the utility of the observed performance for achieving the objectives of the larger organizational unit (Goldstein, 1986; Smith, 1976). Thus, a tank crew's gunnery score would reflect its expected contribution to the success of platoon and company missions. This latter perspective will be pursued.

Gunnery performance is measured on several different types of scales including time, proportion of hits, and dichotomous (yes/no) indices of whether or not particular behaviors occurred. These different indices cannot simply be summed or averaged to yield an interpretable utility score. Furthermore, there are several ways to define time (e.g., opening time, adjustment time, time to shift to a second target, time to hit the first target, time to hit the second target, total time) and proportion of hits (e.g., first round hit probability, subsequent round hit probability, first target hit probability, subsequent target hit probability, total hit probability). In addition, alternative behaviors may be used to achieve hits (e.g., fire COAX or Cal .50 at a truck, fire as a simultaneous or multiple engagement, fire battlesight without lasing or fire precision, fire at the T-72 before or after the BMP). Determining a single utility-based metric for tank gunnery is not straightforward.

To select a metric reflecting the contribution of a tank crew to platoon gunnery success will begin with an analysis of the objective of tank gunnery. That analysis begins with a statement of the ideal criterion on which to judge the proficiency of a tank crew. We'll begin with the following assumption.[5]

The goal of gunnery is to

- *hit as many threat targets as possible,*
- *with as few rounds as possible,*
- *in as short a time as possible,*
- *in order of threat magnitude, and*
- *without hitting friendly vehicles.*

This statement represents a multifaceted criterion that makes conceptual sense, but it must be transformed into a set of scoring procedures that reduces performance to a single number describing overall proficiency. Furthermore, we will add the constraint that two levels of scoring are desirable. One level is to describe proficiency across the set of U-COFT test exercises. The second level is to describe proficiency

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[5]We have focused only on basic gunnery marksmanship, minimizing tactical issues and special firing missions such as suppression.

for each engagement within those exercises. This second level is desirable for studying differences in performance between the various kinds of engagements. The following discussion addresses each facet of the ideal criterion in relation to the capabilities of U-COFT. It begins with problems and issues for scoring each facet at the engagement level, and then presents issues for scoring the test as a whole.

Hit as many threat targets as possible. Every crew is presented the same targets, so ideally all we should have to do is to count the number of targets hit. Unfortunately, dispersion errors are programmed to periodically alter the fall of the round. Although training should include dispersion rounds to teach crews to react appropriately, these dispersion rounds disrupt the testing process. Their occurrence is unpredictable and cannot be standardized. Furthermore, the effects of a dispersion round extend beyond the round itself. When a crew misses because of dispersion, they fire another round which, in turn, reduces the amount of time available to engage other targets. Thus, a dispersion round contaminates measurement throughout the engagement in which it is present. To solve this problem, engagements will not be scored when they include a dispersion round.[6] Therefore, this portion of gunnery will have to be treated as a proportion of targets hit, with the number of targets presented and scored differing for each crew.

When either machinegun (COAX or Cal .50) is used for troop targets, U-COFT indicates percent of target coverage. In order to integrate results from these engagements with the results from the main gun engagements, these percentages will simply be tallied as partial target hits. In other words, a crew would be credited with half a target for 50% coverage, three-fourths of a target for 75% coverage, etc. For machinegun point targets, U-COFT records hits and misses in the same way as main gun targets.

With as few rounds as possible. Again, if it were not for the dispersion rounds, we could simply count the number of rounds fired, at least for the main gun rounds. As suggested above, engagements with dispersion rounds will be eliminated from consideration. A second problem is how to include COAX and Cal .50 rounds in a single index of round use. Counts of machinegun rounds are on the printouts, but how should these be combined with number of main gun rounds? There is some interchangeability among weapons. For example, one crew may shoot COAX at a truck, another Cal .50, and another HEAT with any of these providing a hit. On the other

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[6]Dispersion rounds may also have a hidden effect. When a crew misses because of dispersion with a round that would otherwise have been a hit, U-COFT will print a "MISS(D)," provided that no other rounds are fired at the target. Suppose a crew with such a dispersion round fires again at the same target and gets a hit. Then a "HIT" is indicated and the "MISS(D)" is lost. From the printout, it will appear as if the crew fired two rounds and hit one, when in fact they should be credited with hitting two rounds. With the configuration of U-COFT, this is an unfortunate and intractable scoring problem.

hand, it is wasteful to shoot SABOT rounds at troops and COAX rounds at T-72's, so there is not a simple trade-off between number of main gun rounds and number of machinegun rounds. Firing an inappropriate weapon will result in a target miss, providing sufficient penalty for such errors. A workable solution is to define a machinegun "burst" as a set number of COAX or Cal .50 rounds, and count a burst as equal to a main gun round. FM 17-12-1 indicates that 20-30 round bursts should be fired at point or area targets when firing COAX. Thus, 30 COAX rounds will be counted equal to one main gun round. For the Cal .50, FM 17-12-1 indicates that 10-15 round bursts be fired. Fifteen Cal .50 rounds will be counted as one round. Then total rounds will include main gun rounds plus MG bursts.

Equating machinegun rounds to main gun rounds in this manner is arbitrary. Another solution would be to equate rounds based on total number of rounds available. Theoretically the ideal solution would seem to be based on the expected utility (e.g., amount of damage inflicted on appropriate targets in terms of the overall battle) of a machinegun round or burst compared to a main gun round. However, making such comparisons would require rather complex combat models. In lieu of such analyses, we will use the simple transformation described above. When sufficient data have been collected, psychometric analyses should be conducted to examine the relationship between machinegun engagements and main gun engagements. Alternative transformations (e.g., transformations based on proportion of rounds available) for machinegun rounds should be compared for their relative impact on the overall performance assessment.

In as a short a time as possible. This facet of the criterion implies either (a) measuring how long it takes to hit a fixed number of targets, or (b) measuring how many targets can be hit in a fixed amount of time. In the first case, time should not be limited, and in the second case, the number of targets should not be limited. U-COFT engagements, however, give crews a fixed amount of time to hit a fixed number of targets. There are likely to be some crews that hit all of the targets in an engagement in the time available and some that do not. Some crews may hit no targets. We cannot use time alone, as in (a) above, because there is a ceiling on time available. Time used would be equal for those that hit part of the targets and those that hit none of the targets. Similarly we cannot use hits alone, as in (b) above, because there is a ceiling on the number of targets available. Number of hits would be equal for crews who hit all of the targets regardless of the time they took. Instead, we need to consider the ratio of number of hits to amount of time. Although Bessemer (in preparation) suggests time to hit (time used divided by number of hits) as an appropriate ratio, we have elected to use hit rate (number of hits divided by amount of time). Time to hit cannot be calculated for individual engagements in which crews get no hits because division by zero is not possible. Using hit rate avoids that problem; attaining no hits yields a zero hit rate.

Having selected hit rate as the metric for the "in as short a time as possible" facet of the criterion is only the first step. There are several problems in implementing that decision related to the disruption of dispersion rounds, time limits on U-COFT, whether or not the crew hits all

of the targets, and the time information that is available on the U-COFT printouts. It has already been suggested that engagements with dispersion rounds be left unscored, so that problem is eliminated.

For the crews that hit all of the targets in an engagement, it is possible to directly calculate hit rate as the number of hits divided by the time the last round was fired. U-COFT provides times for target hits.

Some crews will hit only a portion of the targets before time runs out. For these crews, there are several solutions. One option is to divide number of hits by total engagement time. This is not totally satisfactory because the calculation will often be an underestimate, and differentially so for different crews. For example, consider an engagement with 45 seconds of target exposure time, three targets, and two crews who each hit only two of those targets. Using total engagement time, their hit rate would be calculated as 2 divided by 45, or .04 hits per second. However, one of these crews might have hit its first two targets in 32 seconds, and may have been ready to fire on the third target as time ran out. The other crew might have just hit its second target very near the end of time, e.g., after 40 seconds. Clearly, these two crews are different. They can be differentiated by considering only the time it takes to hit the targets, ignoring the time afterwards. Thus, hit rate scores would be .06 hits per second for the first crew (2 divided by 32), and .05 hits per second for the second crew (2 divided by 40). The first crew has the better hit rate, and the hit rate for both crews was underestimated using total time. On the other hand, there may be a third crew who hits two targets in 25 seconds and did not fire again. At that rate (2 hits in 25 seconds) we would have expected to see another hit in the 45 second time period. In this case, .08 hits per second (2 divided by 25), appears to be an overestimate, and the .04 rate (2 hits in 45 seconds) would be more believable. In other words, the .08 hits per second is judged too large because at that rate we would have expected to observe one more hit in the total time period. Thus, if total hits divided by time for the last hit yields a hit rate faster than total hits plus one divided by total time, the estimate based on observed hits divided by total time is reasonable.

Now consider crews that hit one target, then fire again, but fail to hit the second target. If we consider only target hits for these crews, our sample of observations is reduced, and we are throwing away information about how fast the crews are firing. Work by D. W. Bessemer at the U.S. Army Research Institute-Ft. Knox suggests that time to hit be calculated indirectly from hit percent (ratio of hits to rounds) and firing rate information. The same holds for calculating hit rate. It may be estimated as the product of hit percent and firing rate:

$$X \text{ hits/time} = Y \text{ hit/rounds} \times Z \text{ rounds/time}. \quad (1)$$

To make this calculation for an engagement, we would need to know (1) how many hits occurred, (2) how many rounds were fired in an engagement, and (3) when the last round was fired. U-COFT printouts, however, may not supply the necessary time information because firing times

are not printed for every round. Time for the last round will be available only if the last round is a first hit on a target, or if it is the first round fired at a target. Thus, calculation of firing rate is not straightforward.

When the time to fire the last round is not available, firing rate will have to be estimated. Two possible options for estimating firing rate are: (a) number of rounds fired divided by the total time in the engagement, and (b) number of the round with the longest identifiable time divided by that time. Compare four crews that fire four rounds each, a miss and a hit on one target, followed by two misses on a second target. Assume that the engagement is 44 seconds long. The printout will provide a time for the third round, but not for the last round. (See Table 6.) The first method (method A in Table 6) would give the same score for all four crews, i.e., 4 rounds in 44 seconds or .09 rounds per second. Assume that times for the third round are 33 seconds, 39 seconds, 27 seconds, and 24 seconds for crews A, B, C, and D, respectively. The second method, B in Table 6, gives firing rates of .09 rounds per second (3/33) for crew A, .08 rounds per second (3/39) for crew B, .11 rounds per second (3/27) for crew C, and .12 rounds per second (3/24) for crew D. Both methods give the same estimate for crew A; there is no need to choose one estimate instead of the other. For each of the other three crews, the estimates are different and one or the other must be chosen to represent firing rate.

Table 6

Calculating Firing Rate for Four Sample Crews

				Firing Rate Calculation	
Crew	Total Time	Total Rounds	Time of Third Round	Method A = Total Rounds/ Total Time	Method B = Last Round/ Time for Last Round
A	44	4	33 sec	**4/44=.09**	**3/33=.09**
B	44	4	39 sec	**4/44=.09**	3/39=.08
C	44	4	27 sec	4/44=.09	**3/27=.11**
D	44	4	24 sec	**4/44=.09**	3/24=.12[a]

Note: The **bold** hit rate estimate is the one chosen as more appropriate.

[a]This calculation is rejected because it indicates the crew should have fired a fifth round. It is greater than 5 rounds/44 seconds = .11.

For crew B, the estimate based on the first three rounds suggests that we should not have observed the fourth round being fired. Since a fourth round was fired, the estimate from method B is too slow. The estimate based on total rounds and total time (Method A) is used as crew B's time to fire for this engagement. On the other hand, the rate which crew C fired the first three rounds would lead to the expectation of observing them fire only four rounds in the 44 seconds available with a fifth round anticipated at 45 seconds, one second after the engagement ended. Thus, the estimate based on the time to fire the first three rounds (Method B) is appropriate for Crew C. Crew D is a different case. This crew fired its first three rounds very quickly (3 in 24 second). Based on the rate at which these three rounds were fired, we could have expected to have observed five rounds being fired. Five rounds in 44 seconds would be a rate of .11 rounds per second. Because only four rounds were fired, the estimate from method B (.12) is too fast, and method A is chosen.

To calculate hit rate, firing rate is multiplied by hit proportion. Hit proportion is simply the number of hits achieved in the engagement divided by the number of rounds fired.

Using Equation 1, hit rate will be zero for crews with no hits. That is an underestimate for any one engagement; we would expect all crews to hit eventually. However, unless a crew fails to hit on several engagements, their average hit rate across all engagements should be acceptably accurate.

Finally, we must consider crews that fail to fire during an engagement. Neither hit rate nor time to hit can mathematically be calculated for such engagements. However, a zero hit rate will be assigned for the engagement. Again, this is an underestimate for any one engagement since we would expect all crews to eventually fire and hit.

Admittedly, this procedure is complex. Furthermore, it will provide estimates of varying quality depending on how the crew fired the engagement. The estimate should be accurate for crews that hit all targets in an engagement. It should be somewhat less accurate for those that do not hit all targets and do have a time recorded for their last round. The estimate is questionable for crews that have a hit but no time on their last round. Finally, it is always inaccurate for crews with no hits. This is by no means an ideal solution, but it seems to be the best available for the kind of data provided by U-COFT.

In order of threat magnitude. Order of target hits is an important consideration in tank gunnery and one that is scored by U-COFT. This facet of the overall criteria has as its objective, not hitting targets, but avoiding getting hit. More important than order per se is for the crew to hit the threat individual targets faster than their expected rate of being hit. This perspective allows target order to be considered on the same basis as hitting the targets. The problem for this facet of the criterion is not to find a metric, but to set a standard on an already defined metric. That is, we are interested in finding out not only how fast a crew

can hit targets, but if a crew can hit targets fast enough. That is, avoiding being hit is a function of hit rate, and whether or not a crew succeeds is a standard setting problem of determining how fast is fast enough. On the other hand, the target order facet also says that not all targets are equal, e.g., that T-72 targets with their gun tubes directed towards the M1 crew are more important than other targets because they are more likely to inflict immediate damage. Thus, targets differ on their expected rate of hitting the test crew. The inequality between the threat presented by different targets suggests that we may need at least two standards for hit rate: one for "most dangerous targets" and one for other targets.[7]

Without hitting friendly vehicles. The U-COFT test exercise includes two friendly vehicles. Neither of them should be engaged. If either is engaged but not hit, no physical harm is done to the friendly tanks, but time and a round has been wasted. On the other hand, if a friendly vehicle is hit, a penalty should be imposed. Using the idea that a performance score should reflect the utility of that level of performance, the penalty for hitting a friendly tank should reflect the lost productivity of the friendly tank. That is, hitting a friendly tank means that the targets which that tank would have hit must be made up by the remainder of the friendly tanks. Given that tanks normally fight in platoons, this means that each of the three remaining tanks in the platoon must make up the performance deficit. Assuming that the disabled tank was hit half way through the battle, each tank would have to make up one-sixth of the eliminated tank's expected productivity (one-third for each remaining tank times one-half of the battle). Thus, a tank hitting a friendly vehicle would have its U-COFT hits reduced by one-sixth of the expected productivity of the friendly tank, estimated from the average of all crews taking the test. If both friendly vehicles are hit, then on the average the platoon is reduced by half for half of the battle. The penalty should be one-half of the average tank's hits (each remaining tank making up one lost tank for one-half of the battle). A more strict penalty would be to assume that the offending tank is required to make up all of the deficit that it created. Thus, if one of the friendly vehicles is hit, the crew hits would be reduced by one-half of the average tanks' productivity. If both friendly targets are hit, the crew hits would be reduced by the full average. A below average tank would end up with a negative score.

A third alternative which does not depend on group norms is to reduce a crew's performance relative to itself. If one friendly vehicle is hit, the crew's performance would be reduced by one-sixth, using the more lenient criteria above. If both friendly vehicles were hit, the crew's performance would be reduced by one-half. This method is sufficient and is the easiest to handle during data coding until normative information is

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[7]There is a hidden penalty in U-COFT for engaging the wrong target first. If the most dangerous target is not fired on first, it may disappear before the total engagement time has elapsed, thereby reducing the opportunity to fire and hit.

available. When normative data are available, the penalties can be standardized to performance of the fiftieth-percentile crew. Regardless of the specific method, the adjustment of hitting friendly target does integrate fratricide errors with other gunnery metrics in accordance with the magnitude of its effect on total platoon productivity.

On the other hand, imposing a penalty for hitting friendly targets assumes that crews are familiar with U-COFT graphics. Therefore, this penalty is biased against crews with limited experience on U-COFT. Research using crews with varying U-COFT experience should explore the differences in the relative impact of the penalty as a function of crew experience.

Constructing an engagement level composite score. So far the following metrics have been defined for each engagement: (a) number of target hits for the first facet of the criterion, (b) number of rounds for the second facet, (c) hit rate as function of firing rate, and hit probability, for the third facet, and (d) number of friendly targets hit. Interpretation of the first two facets depends on the number of targets and the amount of time in the engagement. One method of making scores comparable across engagements for hits and rounds is to correct for the number of targets in the engagement. Thus, hit average can be calculated as target hits divided by targets, and rounds average can be calculated as rounds divided by targets. Thus, five metrics are identified:

- *Hit average = Hits/Targets,*
- *Round average = Rounds/Targets,*
- *Hit rate = Hits/Time,*
- *Firing rate = Rounds/Time, and*
- *Hit probability = Hits/Rounds.*

We also can specify a sixth variable, time allowed per target, as the time available in the engagement divided by the number of targets in the engagement. The following equations show the relationship between five of the metrics and suggest possible overall gunnery proficiency metrics:

$$\text{Hits/Time} = \text{Hits/Rounds} \times \text{Rounds/Time Used, and} \quad (2)$$

$$\text{Hits/Targets} = \text{Hits/Rounds} \times \text{Rounds/Time Used} \times \text{Time Allowed/Targets.} \quad (3)$$

Equation 3 shows that hits per target is a function of hit probability (hits/rounds), firing rate (rounds/time used) and target exposure time (time allowed/targets). Time allowed per target is a function of the test and, at the engagement level of scoring, it is constant for all crews. The other terms are performance variables.

Note that hits per targets cannot be calculated directly from the U-COFT printout by dividing number of hits by number of targets. This is because the estimation procedure described for calculating firing rate, the second term, may use values for rounds and time that may not match the

values in the other two terms. For example, assume that a crew fires an engagement that has 4 targets and 45 seconds available. They hit two targets with their first three rounds, fire at a third target and miss, then time runs out. The U-COFT printout shows their last round was fired at 40 seconds. If we were to divide 2 hits by 4 targets, we would get a hit proportion of .50. On the other hand, following the rules outlined above for calculating hit rate, we have:

(2 hits/4 rounds) x (4 rounds/40 seconds) x (45 seconds/4 targets) = .56 hits per target.

In a sense, the crew is given credit for the preparation work it presumably completed in the 5 seconds from the time it fired the last round to the end of the engagement.

Since hit rate (hits/time) equals hit probability (hits/rounds) times firing rate (rounds/time), hits per target can also be expressed as a function of hit rate and target exposure time:

Hits/Targets = Hits/Time Used x Time Allowed/Targets. (4)

If total time available and number of targets are interpreted as engagement standards, the hits per target index is an index of engagement effectiveness. If a crew hits all targets in exactly the time available, hits per targets equals 1. If all targets are hit in less than the time allowed, the hits per target is greater than one. If not all targets are hit, the hits per target is less than one. If the amount of time that threat vehicles are exposed equals their expected time to hit a friendly vehicle, the hits per target indexes would represent threat capabilities. Then hits per target scores above 1 would indicate survival and hit per target scores below 1 would indicate that the crew would become a casualty. On the other hand, there are two reasons for dropping the time per target term. First, its use would give the illusion that the engagements are calibrated against expected threat conditions and that any given value means the same level of performance utility across all engagements. Whether or not this is true is unknown. Second, time per target is an engagement constant, not a crew performance index. It adds nothing to the differentiation between crews. In theory, the hits to targets ratio is a potentially useful metric of tank gunnery effectiveness, but it is not sufficiently developed to put into practice. Dropping the time per target term yields hit rate as the basic criterion of gunnery proficiency.

Hit rate, adjusted for friendly vehicles hits, is a metric that incorporates three of the facets of the tank gunnery criterion (time, number of hits, and friendly vehicles hit). In addition, it can serve as an approximation for the survival facet of the criterion target order.

The remaining facet, number of rounds used, was cancelled out in the calculation of hit rate, and the average rounds metric (rounds per target)

defined earlier was not included. We must add back into the equation an index of how fast rounds are being used, with fewer rounds being better. Time per round is appropriate when used in conjunction with hits per time. That is, the crew should have high hits per time, with few rounds during that time. To give the rounds-to-time ratio an ascending value for better performance, time per round is used. For a given hit rate, more time between rounds is better. Multiplying hit rate by round rate yields:

$$\text{Hits/Time} \times \text{Time/Rounds} = \text{Hits/Rounds, or hit probability.} \quad (5)$$

The value of time is cancelled out.

Thus, hit rate, our metric for incorporating speed, ignores rounds used. Hit probability, our metric incorporating rounds used, ignores speed. On the other hand, at least in the short run, hit rate is influenced by rounds used to the extent that having to fire extra rounds reduces speed. In the long run this is an illusion. Two crews with different hit probabilities can have equal hit rates because the crew with the lower probability fires faster (and uses more rounds). Before an overall index of gunnery proficiency can be identified, further consideration of the meaning of "in the long run" is necessary.

There is a limit on the number of rounds a crew can fire before it has to remove itself from the battle and reload. We need to make some assumptions about how long a battle may last and whether or not a crew could run out of ammunition. If the battle is so short that crews will not run out of ammunition, then hitting targets fast is all that is important. This makes hit rate the measure of choice. If the battle is long enough or reloading opportunities infrequent enough that crews can run out of ammunition, then hit rate must be adjusted for how long a crew can fire before it runs out of ammo. That is, given a certain number of rounds and a period of time long enough to expend those rounds, how many targets can be hit? If all crews run out of ammo, crew hit probability is the measure of choice. The rank order of crews may not be the same when the battle is short compared to when it is long.

For example, assume that there are four crews (A, B, C, and D) with the performance capabilities illustrated in Table 7 and a load of 45 rounds, where hit rate = hit probability x firing rate. From these data, Figure 1 gives the expected target hits for 10 to 15 minutes of total contact with threat tanks (and assuming no shortage of tanks to shoot). Contact could occur continuously or intermittently. As long as there were no opportunities to reload, the conclusions regarding sustainment would be the same.[8]

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[8]For simplicity we are ignoring the time it takes to transfer rounds from the semi-ready rack to the ready rack.

Table 7

Sample Data for Comparing Hit Rate and Hit Probability

Crew	Firing Rate	Hit Probability	Hit Rate	Sustainment
A	3 rd/min	.83	2.5/min	15 min
B	4 rd/min	.625	2.5/min	11.25 min
C	3 rd/min	.67	2/min	15 min
D	4 rd/min	.50	2/min	11.25 min

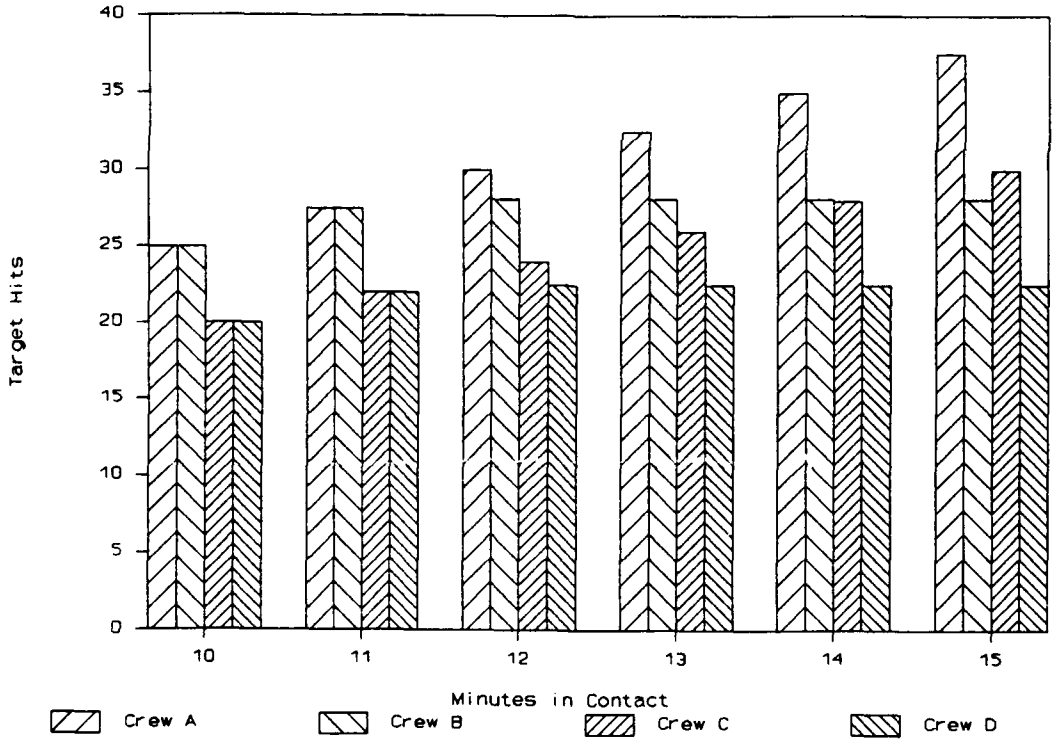

Figure 1. Comparison of target hits at different times for crews with different hit probabilities and hit rates.

Crews A and B have the best hit rates at 2.5 hits per minute. They differ, however, in firing rate and hit probability such that Crew A can sustain firing for 15 minutes, while Crew B runs out of ammunition at 11.25 minutes (again, assuming 45 rounds available). If we were to judge proficiency on only one battle of 11 minutes or less, Crews A and B would be considered equal. For a longer battle, Crew A is superior to Crew B. There is an analogous comparison between Crews C and D. That is, Crews C and D would be judged equal on a battle of 11 minutes or less, but Crew C would be superior for longer periods of contact.

Comparing Crew B with Crew C, Crew B has the lower hit probability, but also the faster firing rate and higher hit rate. But Crew B will run out of rounds while Crew C can sustain firing. At about 14 minutes Crew C catches Crew B in number of target hits. Therefore, if the contact were to last less than 14 minutes, Crew C would hit fewer tanks than B. But if contact goes on 15 minutes or longer, Crew C hits more tanks than B. Crew B goes from tied for the best to 3rd place in the rank ordering of crews, depending on the length of the battle.

The fallacy in this analysis is that if hit rate is not fast enough, even if running out of ammunition is possible, the tank will be overrun by threat forces. Hit rate simply cannot be ignored. On the other hand, two crews with equal hit rates but different round usage cannot be considered equal. The one firing fewer rounds can sustain itself longer. A comparison of crews with somewhat different hit rates breaks down. For example, compare a crew that hits 80% of 20 targets in 8 minutes with 24 rounds to a crew that hits 72% of 25 targets in 7 minutes with 28 rounds. Which crew is better? The first crew has a lower hit rate but uses fewer rounds. What is needed is a way of equating crews on hit rate and then estimating how long they could sustain that rate.

The Speed-Accuracy Trade-Off

The missing piece of information for equating crews on hit rate is a function relating firing rate to hit probability. For motor skills that have both speed and accuracy requirements, there is often a trade-off. For a given individual or crew, higher speed (i.e., rates of fire) are predictive of lower accuracy (i.e., hit probability). The relationship is called a speed-accuracy operating characteristic (S-AOC; Pew, 1969). We can assume that individual crews have some response bias to fire at a particular rate, achieving hit probabilities commensurate with those rates. With an S-AOC function, we could predict their hit probabilities if they were to alter their firing rate to a given standard. We could also answer the following: If a crew were to fire at a designated rate and would be allocated a designated number of rounds, how long could it sustain firing and how many hits would it achieve? The designated hit rate could be selected to ensure short term survival. The number of rounds can be based

on tank storage capacity.[9] Thus, either sustainment or expected hits would provide an overall proficiency metric which takes into account both survivability and hits. Unfortunately, we currently do not know the shape of these functions or, for that matter, whether they actually exist for tank crew gunnery proficiency.

Compromise Solution

Our suggested solution is to use hit rate as the overall metric of gunnery proficiency, with adjustments as noted above for hitting friendly vehicles. That is, hit rate provides the primary continuum for overall comparisons among crews' proficiency.

Compared to our conceptual statement concerning crew gunnery, there are two compromising assumptions underlying the acceptance of hit rate as the single criterion of gunnery proficiency. One is that round usage is secondary to hitting targets. That is, if hit rate is not fast enough, the tank itself will be hit and the saving of rounds is irrelevant. Round usage can be examined as a supplementary metric. Second, hit rate has not been weighted by target order so that first target's time (opening time) in a multiple target engagement is no more important than the time to hit any of the targets. As indicated above, this is an oversimplification if first targets are more dangerous than subsequent targets. However, if targets are equally dangerous or if targets are not easily ordered because of the chaotic nature of the future battlefield, then the assumption is reasonable. Opening time may give some diagnostic information about how time is being used, but it will not be differentially weighted in the proficiency criterion of hit rate.

Hit rate has a long history of use in combat modeling (e.g., Battilega & Grange, undated; Taylor, 1980) and has been accepted by the Armor community as a fundamental measure of tank gunnery performance. For example, scoring of points for Tank Table VIII is based on a sliding scale

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[9]The solution to the question is achieved by first expressing the speed-accuracy operating characteristic as

Hit probability = *f* (Firing Rate). (a)

This S-AOC function can then be combined with the hit rate functions defined earlier. That is, begin with the hit rate function:

Hit rate A = Hit probability B x Firing Rate C, or (b)

Hit rate A = Hit probability B x (Rounds D/Time E). (c)

Hit rate A and rounds D are the designated constants, and we need to solve for time E. Equation a, the S-AOC function that expresses hit probability in terms of firing rate, can be substituted into equation b or c:

Hit rate A = *f* (Firing Rate C) x Firing Rate C, or (d)

Hit rate A = *f* (Rounds D/Time E) x (Rounds D/Time E). (e)

Equation e could then be solved for E to give expected sustainment. Sustainment time could be substituted into the hit rate formula to give expected number of hits:

Expected hits = Hit Rate A x Time E. (f)

derived from number of hits and elapsed time. The scale "slides" in relation to expected threat capabilities. That is, points are assigned to various friendly hit rates by comparing friendly hit rates to expected threat hit rates, yielding a hit exchange ratio (HER) of friendly hits to threat hits. Given that expected threat capabilities are the same for all crews, friendly hit rate is the performance measure on Table VIII that differentiates crews. The Directorate of Training and Doctrine, ORSA Division, has recently applied a similar conceptualization to the scoring of Tank Table XII.

In order to calculate hit exchange ratios for U-COFT, an expected threat hit rate for the kinds of engagements represented in the U-COFT test would be needed. Expected threat hit rate was not calculated, however. Until further investigation of how U-COFT levels of performance match actual M1 tank performance, comparing U-COFT scores threat capabilities is premature. However, hit rate is the U-COFT measure most likely to rank order crews in the same way as M1 tank performance.

Calculation of U-COFT Scores

Hit rate, adjusted for hits on friendly targets, is the recommended metric for assessment of overall crew proficiency. Hit rate is calculated for each engagement from information on U-COFT printouts on rounds fired, hits, and time. Overall hit rate is calculated from the weighted averages for firing rate and hit probability, where engagement firing rates and hit probabilities are weighted by the number of targets in the engagement. Thus, targets are weighted equally in the calculation of overall hit rate.

Because hit rate is a deficient criteria with respect to use of rounds, the components of hit rate, hit probability and firing rate, may be used to qualitatively supplement the interpretation of hit rate differences. Again, for any given hit rate, higher hit probability and lower firing rate are indicative of efficiency in the use of rounds. However, comparisons among crews with different hit rates becomes tenuous.

Although the focus has been on assessing overall proficiency, a number of diagnostic metrics are also identified as useful for interpreting differences in overall proficiency. In general, these indexes refer to aspects of performance that underlie hit rate. Included are

1. firing rate,
2. hit probability,
3. average opening time,
4. average number of classification errors,
5. average number of system management errors, and
6. average miss distance.

They may be used to infer reasons for differences in hit rates among crews or groups of crews. Detailed procedures for calculating recommended U-COFT scores are presented in the handbook in Appendix A.

Reliability and Validity

No information on the reliability of the exercises is currently available. Information on validity is limited to the content sampling information presented in Table 5 and to the discussion of scoring procedures presented above. The validity of the scoring procedures provided on the U-COFT printout has been reviewed elsewhere (Hoffman and Morrison, 1988). That review suggested the use of additional observations of crew performance, recorded on scoresheets, to support interpretation of U-COFT scores. Where possible, use of supplementary scoresheets is suggested.

Interpretation of U-COFT scores from these exercises in terms of expected performance on the actual M1 tank is also uncertain at this time. Previous research comparing various U-COFT exercises with M1 Tank Table VIII has not been able to support the conclusion that U-COFT and Table VIII are measuring the same skills (Hoffman and Morrison, 1988).

Standards of Performance

Although three of the four exercises chosen for this test are from the U-COFT "qualification" series, no qualification standards are implied by this test. Until additional research and formal standard setting procedures are conducted, the use of any implied mastery scales (e.g., go versus no go) is inappropriate. In addition, normative data do not yet exist for this test.

Summary

This report describes in detail the construction of a standardized test of M1 gunnery proficiency for tank commanders and gunners using the M1 U-COFT. The purpose of the test is to a provide a standardized research tool for integrating future research efforts in M1 tank gunnery.

Preparation of the test included four activities. First was selecting U-COFT exercises to represent the domain of conditions defined by M1 Tank Table VIII. Second was detailing administration procedures and composing a test administrator's script. The third activity was preparing a test administrator's orientation guide outlining general dos and don'ts of performance testing. The final activity was selecting performance measures and writing scoring instructions.

The U-COFT test is composed of four U-COFT exercises comprising 23 different moving (offensive) and stationary (defensive) engagements against both moving and stationary, and single and multiple targets. Special presentation instructions were developed for U-COFT Instructor/Operators to follow instead of using their routine U-COFT training procedures. Hit rate was identified as the most appropriate composite measure of gunnery performance. Instructions were prepared for calculating hit rate for each engagement in the test and for calculating hit rate for the test as a whole. Additional measures were identified for supplementary analyses of

performance. These include firing rate, hit probability, average opening time, average miss distance, and average numbers of classification errors and system management errors. A handbook describing procedures for using the text is attached as Appendix A.

Use of this test in future tank gunnery research projects should facilitate our ability to integrate research in tank gunnery and thereby increase our understanding of performance requirements in tank gunnery. For example, this test could be used in studies of training progress on U-COFT, in studies attempting to predict crew performance on other gunnery exercises such as Tank Table VIII, or in studies comparing the effects of alternative training strategies on crew gunnery performance.

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APPENDIX A

Handbook for Administering and Scoring a Unit-Conduct of Fire Trainer (U-COFT) Test of M1 Gunnery Proficiency

The purpose of this handbook is to present instructions for administering and scoring a M1 Unit-Conduct of Fire Trainer (U-COFT) test of gunnery skills of tank commanders and gunners.

Use of the Test

The primary purpose of this test is to provide a standardized method for assessing a crew's (i.e., TC and gunner) gunnery proficiency on U-COFT. A number of research efforts have already used U-COFT to assess crew proficiency (Abel, 1987; Black & Abel, 1987; DuBois, 1987; Graham, 1986; Smith & Graham, 1987; Witmer, 1987a, 1987b). The exercises and scoring varied across these studies. Advancing the understanding of tank gunnery skill acquisition and performance measurement is an reiterative process. Any one study cannot answer all questions. While each study may use performance measures of particular interest, it is also important to have a set of standardized scoring procedures that can be used to tie together the results and conclusions of these studies. Furthermore, if a single summary measure could be identified to rank tank crews, the process of drawing simple, straight forward conclusions from any one study or across studies would be greatly facilitated. If future research supports their validity, U-COFT proficiency scores could be used for such purposes as evaluating progress in U-COFT training, predicting crew performance on Table VIII, predicting crew contributions to company tactical missions, or comparing crew scores in various research experiments.

The test emphasizes measurement of overall proficiency using hit rate as the single composite measure of gunnery performance. In addition, several other measures are recommended for supplementary analyses. These include firing rate, hit probability, average opening time, average miss distance, and average numbers of classification and system management errors.

Until more is learned about its reliability, validity and performance norms, use of the test should be limited to research applications. Data collected should be shared with ARI, Ft. Knox, Kentucky in order to build a base for estimating reliability and establishing performance norms. U-COFT was built for training, and therefore standardized testing is not straightforward. Researchers using the test should have some familiarity with U-COFT, and they will need to acquire the assistance of a qualified U-COFT Instructor/ Operator to administer the test.

The test should not be used for routine training because such use often leads to teaching the test. Obviously that can undermine interpretation of test scores.

Contents of the Handbook

This handbook contains four separable parts. Each part should be reproduced and distributed as needed. The first part, "Instructor/Operator Orientation for Administering the U-COFT Test of M1 Gunnery Proficiency," is a handout to be used to orient U-COFT I/O's administering the test. It emphasizes the differences between the training routine they normally use and the requirements of a standardized test. The training habit of giving feedback and coaching can be particularly troublesome in the testing context.

The second part of the handbook, "Administration of a U-COFT Test of M1 Gunnery Proficiency," gives detailed test set-up and administration procedures. It is intended to be complete and should be followed to the letter, as required by any standardized test.

The third part, "Scoring the U-COFT Test of M1 Gunnery Proficiency," presents the procedure required for scoring the U-COFT test. Unfortunately, it is cumbersome and requires considerable effort to retrieve and code the appropriate information from U-COFT printouts. One should not expect to be able to give crews immediate feedback on their performance. However, the procedure will produce a set of meaningful scores.

The final part, "Interpretation of U-COFT M1 Gunnery Scores," presents some brief information regarding interpretation of the U-COFT scores. The text of the technical report describes their derivation in detail.

Instructor/Operator Orientation for Administering the U-COFT Test of M1 Gunnery Proficiency

The role of the U-COFT I/O (Instructor/Operator) is the key to the successful implementation of this U-COFT test of gunnery proficiency. This orientation provides important background information needed to perform that role. The specific steps for conducting the test are presented in a separate document, "Administration of a U-COFT Test of M1 Gunnery Proficiency."

Testing Versus Training

No matter what the subject or what kind of equipment is used, there are several differences between conducting training and administering a test. Consequently, your role as a test administrator will be very different from your role as an instructor. It is important that you understand the differences between training tank crews and testing tank crews.

First, in order for test scores to be interpretable, they must describe performance in a well-defined situation. Thus, the test procedures are spelled out in detail, and the test must be administered to all crews in exactly the same manner. While training sessions are flexible and tailored to the needs of the crews, **testing sessions must be rigidly the same for all crews.** If not, the test results will be ambiguous. Detailed instructions have been prepared for you to follow each time you administer the test.

Second, during training, instructors do all that they can to help crews improve their performance. Coaching and feedback are freely given to help each crew improve. The training session is intentionally dynamic. In contrast, the goal of testing is to assess how much a crew knows at the time of the test. Thus, it is crucial that **no coaching or feedback be given during testing.**

Third, the test must be capable of assessing a wide range of skill levels. To measure the most proficient crews, the test must be challenging. Some crews will do very well on the test, while inexperienced crews may make many mistakes. It is necessary for this type of test to **obtain variability in performance.** There is no pass/fail cut-off set for this test. Rather, we simply want to know how well crews can perform, and we expect a wide range of performance.

These differences between training and testing require that, as test administrator, you must

1. ***always follow every detail of the test procedure,***
2. ***provide NO feedback or coaching, and***
3. ***treat every crew alike, regardless of ability.***

Administering the test is not easy. First, you must break many habits and go against the training routine you are accustomed to as an I/O. Second, you will find it almost agonizing not to be able to help the crews perform. As a good instructor, you will want to correct mistakes; as a good test administrator, you can't! In order to conduct the test smoothly, you will have to

1. ***read and study the procedure and,***
2. ***practice.***

Administration of a U-COFT Test of M1 Gunnery Proficiency

Materials and Equipment

2 CVC Helmets
2 M25 Protective Masks
M1 U-COFT
Instructions

Set-up prior to arrival of crew

If not previously completed, the U-COFT should be aligned. The alignment procedure is attached as a Supplement to these instructions.

U-COFT should be powered-up and in sustainment training mode. Use rapid access, entering XXX for names and vehicle numbers. Set crew compartment switches as follows:

Master power - On
Turret power - On
Laser - Last return
GPS - 3X
Mode - Normal
Ammo Select - SABOT
TIS - Standby
TIS Magnification - 3X
Filter/Clear/Shutter - Clear
Main gun - Safe

NOTES to I/O:

On the following pages, everything printed in **bold and highlighted** is to be read aloud. Do not read the U-COFT provided instructions for any of the exercises.

If a crew gets killed at any time, immediately allow the exercise to resume.

Follow all of the TC commands to driver and loader exactly as they are issued. Do not add responses. For example, in a stationary own tank engagement if the TC forgets to have the driver "move out," do not move the tank. There are, however, two exceptions to this rule:

(1) If the TC says "Driver, move out," and the tank is already enfilade, tell the TC "You are out."

(2) If the TC says "Driver, move back," and the tank is already defilade, tell the TC "You are back."

Before the test

Obtain crew members' names and make sure they have had, at a minimum, a U-COFT familiarization exercise. If either crew member has never fired U-COFT, consult with the person directing the testing session. Write the crew members' names on a log sheet.

Have the crew members enter U-COFT, put on their CVC, and adjust their seats, eyepieces, volume on CVC, reticle brightness, etc.

Exercise One - 346331

Call up exercise 346331 (answer "no" to the inquiry about the desert data base). Make a commo check and have the TC turn on the master power switch, if it has gone off.

Run the exercise just long enough to bring up the picture. Freeze the exercise.

Read the following to the crew:

"Attention. This is a test of your gunnery skills. It consists of four U-COFT exercises and will last approximately one hour. You will be firing from both moving and stationary positions at moving and stationary targets. The exercise includes:

- day engagements,
- night engagements,
- single target engagements,
- multiple target engagements,
- engagements under NBC conditions,
- and engagements for TC only.

"Although you are not under actual combat conditions, you must act as if you are by using correct procedures and engaging targets as quickly and as accurately as you can. Assume the U-COFT is your tank and be prepared to make the best use of your tank's capabilities under the conditions presented. Do everything as you would in your own tank. I will act as your platoon leader, and will periodically give you firing sector information. Assume you are tank A22 (alpha two two). Assume that all U.S. made tanks are friendly and all other targets are hostile.

"Because this is a test of your skills, I will not be coaching you or critiquing your performance like I would in a normal training session. You will not be scored GO or NO GO, but you will be scored for how much you know and how well you do. The exercises have been chosen to be challenging. You are in a test situation. You are on your own. Remember there are single and multiple target engagements and that you are to engage all targets. Use all of the correct doctrine. For example, engage helicopters with SABOT regardless of what your previous U-COFT experience has been. Are there any questions?"

Repeat any information from above as necessary to answer questions.

"In this first exercise, your platoon is on the move in a movement to contact, and has just moved into a line. SABOT is loaded and battlesight range is 1200 meters. Your sector is your direct front. You are to engage all threat targets within your sector. Are there any questions?"

Repeat any information from above as necessary to answer questions.

Say: "O.K. Let's begin."

Unfreeze the exercise.

Engagement 1. Five seconds before the first target is to appear announce: "Contact. Front. Fire."

Watch the target location indicator on the situation monitor. If the targets are up or will be up within 5 seconds and the crew has the main gun directed more than 20 degrees away from the closest target direct them back by saying: "A22, you are out of sector. Traverse right/left." Provide no other feedback during the course of the exercise.

Let the exercise continue to run to completion.

Wait until the exercise completes and freezes on its own. Announce: "Cease Fire. Relax for a minute."

PRINT THE SITUATION MONITOR, THE PERFORMANCE ANALYSIS AND THE SHOT PATTERN.

- - DID YOU PRINT THE LAST EXERCISE? - -

Exercise Two - 346110

NOTE to I/O: In this exercise you will be giving some special instructions for engagements 2, 3, and 4.

Call up exercise 346110. Have the crew reset any switches necessary to run the exercise as indicated by the U-COFT monitor. Run momentarily to bring up the first picture.

Read the following: "Attention. In this exercise, your platoon is defending from a battle position and your tank is turret down. SABOT is loaded and battlesight range is 1200 meters. Before we continue we will define the boundaries of your sector.

NOTE to I/O: While you are directing them to their sector limits, watch the time. Do not let the first target appear. If necessary, restart the exercise.

"When I unfreeze the exercise I want you to traverse right." Pause. "Traverse right. Stop at the left edge of the two hedge rows." Unfreeze the exercise.

When they are laid correctly tell them to "Stop" and freeze the exercise.

"Do you see the hedge rows? This is the right limit of your defensive sector. When I unfreeze the exercise, I want you to traverse left." Pause. "Traverse left. Stop in between the two hedge rows." Unfreeze the exercise.

When they are laid correctly tell them to "Stop." and freeze the exercise.

"Do you see the hedge rows? This is the left limit of your defensive sector. You are to engage all threat targets within your sector. Are there any questions?"

Repeat any information from above as necessary to answer questions.

Say: "Before we begin, let me warn you that I will be interrupting this exercise to give you some special instructions. Let's begin."

Unfreeze the exercise.

Engagement 1. Five seconds before the first target is to appear announce: "Contact. Front. Fire."

Monitor the view from the forward unity periscope, FUP. If at any time the crew has the main gun directed outside of their sector, direct them back in by saying: "A22, you are out of sector. Traverse right/left." Provide no other feedback during the course of the exercise.

Engagement 2. After all of the first set of targets (a T72 and troops) are hit or disappear, freeze the exercise and announce: "GAS! GAS! GAS!" Look in the crew compartment to insure the crew has put on their protective masks. Unfreeze the exercise.

Engagement 3. After all of the second set of targets (3 T72s) are hit or disappear, freeze the exercise and announce:

"ALL CLEAR!. For the following engagement, assume the gunner is injured and cannot perform. Tank commander, you are on your own. The gunner cannot switch magnification for you during the engagement. Prepare your tank. Tell me when you are ready."

Unfreeze the exercise when the TC indicates he is ready.

Engagement 4. After all of the third set of targets (3 more T72s) are hit or disappear, freeze the exercise and read the following: "You may now continue with your full crew." Unfreeze the exercise.

Wait until the exercise completes and freezes on its own. Announce:

"Cease Fire. Relax for a minute."

PRINT THE SITUATION MONITOR, THE PERFORMANCE ANALYSIS AND THE SHOT PATTERN.

- - DID YOU PRINT THE LAST EXERCISE? - -

Exercise Three - 346220

NOTE to I/O: In this exercise you will be giving some special instructions for engagements 3 and 4.

Call up exercise 346220.

Read: "In this exercise, your platoon is defending from a battle position. It is night and your tank is turret down. Prepare your tank for night operations. DO NOT MOVE THE TURRET."

Unfreeze the exercise while they make their adjustments. Let the time to first target run down to 5 seconds. Freeze. If they did not have enough time to make their adjustments, restart the exercise.

Ask: "Are you ready?. Without moving the turret, look into your sights and I will define your sector. The right limit is the trees at the extreme right edge of your sight picture. Do you see them? The left limit is the trees to the left of the barn at the extreme left edge of your sight picture. Do you see them? You are to engage all threat targets within your sector. SABOT is loaded and battlesight range is 1200 meters. Are there any questions?

Repeat any information from above as necessary to answer questions.

Say: "O.K. Let's begin."

Unfreeze the exercise.

Engagement 1. Announce: "Contact. Front. Fire."

Monitor the view. If at any time the crew has the main gun directed outside of their sector, direct them back in by saying: "A22, you are out of sector. Traverse right/left." Provide no other feedback during the course of the exercise.

Engagement 3. After all of the first and second sets of targets (5 T72s) have been hit or disappear, freeze the exercise and announce: "GAS! GAS! GAS!" Look in the crew compartment to insure the crew has put on their protective masks. Unfreeze the exercise.

Engagement 4. After all of the third set of targets (a T72, a HIND-D and a BMP) have been hit or disappear, freeze the exercise and announce:

"ALL CLEAR!. For the following engagement, assume the gunner is injured and cannot perform. Tank commander, you are on your own. The gunner cannot switch magnification for you during the engagement. Prepare your tank. Tell me when you are ready."

Unfreeze the exercise when the TC indicates he is ready.

Wait until the exercise completes and freezes on its own. Announce: "Cease Fire. Relax for a minute."

PRINT THE SITUATION MONITOR, THE PERFORMANCE ANALYSIS AND THE SHOT PATTERN.

- - DID YOU PRINT THE LAST EXERCISE? - -

Exercise Four - 315631

Call up exercise 315631.

"This is the last exercise. Your platoon is on the move in a movement to contact, and has just moved into a line. Your tank has been hit by machinegun fire. Your GPS, TIS, stab and LRF are out. Prepare your tank for emergency operation. SABOT is loaded and battlesight range is 1200 meters. HEAT battlesight range is 900 meters.

"Your sector is your direct front. You are to engage all threat targets within your sector. Are there any questions?"

Repeat any information from above as necessary to answer questions.

Say: "O.K. Let's begin."

Unfreeze the exercise.

Engagement 1. Five seconds before the first target is to appear announce: "Contact. Front. Fire."

Watch the target location indicator on the situation monitor. If the targets are up or will be up within 5 seconds and the crew has the main gun directed more than 10 degrees away from the closest target, direct them back by saying: "A22, you are out of sector. Traverse right/left." Provide no other feedback during the course of the exercise.

Let the exercise continue to run to completion.

Wait until the exercise completes and freezes on its own. Announce: "Cease Fire. The test is complete. You may come out."

PRINT THE SITUATION MONITOR, THE PERFORMANCE ANALYSIS AND THE SHOT PATTERN.

Put the crews name on the first page of the printouts. Do not tear the pages off the printer.

Supplemental Instructions
Procedure for Aligning TIS and GPS Reticles

Exercise 111310 - TIS and GPS alignment

Call up exercise 111310.

Switch the GPS to 10X and place the day reticle on the top corner of the white boresight panel.

Null out drift by using the AZ and EL Normal Mode drift knobs. Push the knobs and turn while watching the effect on drift. (NOTE: YOU MUST DEPRESS THE PALM SWITCHES AND HOLD WHILE NULLING THE DRIFT.)

When the drift has been nulled out, move the reticle to the center of the panel.

Lase and fire observing the strike of the round. The round should strike within the circle at the center of the boresight panel.

Place the center dot of the GPS reticle on the top left corner of the boresight panel. (CAUTION: DO NOT TOUCH THE CONTROL HANDLES ONCE THE RETICLE HAS BEEN PLACED.)

Turn the TIS from STBY to ON.

Place the FLTR/CLR/SHTR switch to SHTR.

Switch the TIS POLARITY switch to WHITE HOT and adjust the TIS RETICLE control for a black reticle.

Look into the sight to see where the TIS reticle is in relationship to the day reticle. WARNING: DO NOT MOVE THE TURRET!

Turn the TIS BORESIGHT knobs (AZ and EL) until the center dot of the TIS reticle is perfectly aligned with the day reticle at the left tip of the boresight panel.

Engage the power control handles and bring the TIS reticle to the center of the boresight panel.

Lase and fire, checking the strike of the round relative to the round fired from the daysight.

If the TIS round does not hit within the circle at the center of the boresight panel, repeat the entire alignment procedure.

Scoring the U-COFT Test of M1 Gunnery Proficiency

Scoring U-COFT

Hit rate, with a penalty for hits on friendly targets, is the recommended metric for assessment of overall crew gunnery proficiency on the U-COFT test. Hit rate is calculated for each engagement from firing rate and hit probability estimates using information from U-COFT printouts. In addition to hit rate, several other measures are calculated as supplementary indexes of crew proficiency.

Table A-1 presents a step-by-step procedure for computing firing rate, hit probability, and hit rate. These scoring procedures were derived from the analysis of our ideal criterion statement presented in the report. The rationale for this scoring system is described in that presentation. Because of the U-COFT design, calculation of these metrics is not straightforward. Calculation of firing rate is particularly cumbersome. Although a qualified U-COFT I/O can administer the test, scoring is sufficiently complicated to require a research assistant with some data analysis experience.

Six sample engagements have been selected as examples of implementing the scoring rules. The relevant information from the situation monitor, performance analysis, and shot pattern printouts has been extracted for a sample crew and presented in Tables A-2, A-3 and A-4. A coding sheet that shows the coding for the sample crew is given in Table A-5. For illustration, we will go through each step of the scoring procedure.

Scoring steps are numbered to match the lines for recording information on the sample code sheet in Table A-5, i.e. step 7 in Table A-1 corresponds to line 7 in Table A-5. Before recording any information, however, the situation monitor printout (SM) is examined for dispersion rounds. Engagement D shows a MISS(D) for the T72. Consequently, none of engagement D is scored. Periods are inserted in the coding sheet to indicate missing data.

For the first step of the scoring rules, enter the number of targets in each engagement. For engagement A, "troops" are counted as one target. Hits are counted for step two. The performance analysis printout (PA) shows that 25 percent of the troops were covered in engagement A. Therefore, .25 is recorded for number of hits for engagement A. Number of rounds fired are counted for step three. Number of rounds fired on targets are on both the SM and the PA. Rounds fired at non-targets are coded under system management errors on the PA. The PA indicates that 71 COAX rounds were fired in engagement A. Using the conversion chart in Table A-1, the 71 COAX rounds is counted as equivalent to 2 main gun rounds. Similarly, the 55 COAX rounds in engagement F is recorded as 2 main gun rounds on the sample code sheet. For engagement C, two rounds were fired in the engagement, one at the first T72 and one at a non-target. Identification of the non-target round is from interpretation of the classification error codes discussed below and in step 8 in Table A-1.

Table A-1

Procedure for Scoring U-COFT Test

With two exceptions, engagements that are marked with a "MISS(D)" or "KILL(D)" are not scored. They should be left blank or coded to indicate a missing value. If there is a "MISS(D)" on a friendly vehicle in either Engagement 4 of Exercise 1, or Engagement 5 of Exercise 4, score step 12 as hitting the friendly target.

Score Engagement 5 of Exercise 4 (the single M1 vehicle) on step 12 only.

For each engagement:

1. Record the number of threat targets presented.

2. Count the number of hits (threat targets only). Tally Cal .50 or COAX % coverage data as partial hits, e.g., 50% coverage equals .5 hits, 75% coverage equals .75 hits.

3. Count the number of main gun rounds or number of machinegun bursts fired. Use the following tables to convert COAX and Cal .50 rounds to main gun equivalence:

COAX Rounds	Cal .50 Rounds	Main Gun Equivalence
1 - 45	1 - 22	1
46 - 75	23 - 37	2
76 - 105	38 - 52	3

Be sure to check classification errors for rounds fired at non-targets.

(table continues)

Table A-1 (continued)

For each engagement:

4. Calculate firing rate according to the results of the engagement according to the following rules. In each case if (a) the only time available for a main gun round is a "kill time," subtract one second to estimate firing time, and (b) if the rounds are COAX or Cal .50, use kill time minus one second.

   a. If all of the targets are hit:
   Firing rate = number of rounds fired/time for firing the last round.

   b. If rounds are fired, one or more targets are not hit, and a time is available for the last round, calculate:

      A = Total number of rounds fired/time for firing the last round,

      B = Total number of rounds fired/total time (see below), and

      C = (Total number of rounds fired + 1)/total time.

   Use A as the estimate for firing rate unless it is greater than C. If A is greater than C, use estimate B for firing rate.

   c. If rounds are fired, one or more targets are not hit, and a time is not given on the printout, first identify the round that has the largest firing time, i.e., round number 1, round number 2, etc. Then, calculate:

      A = Number of the last round with a time/Time for that round,

      B = Total number of rounds/Total time (see below),

      C = (Total number of rounds + 1)/Total time.

   If B is greater than A, use B for firing rate.
   If A is greater than B and A is less than C, use A.
   If A is greater than B and A is greater than C, use B.

   d. If no rounds are fired, set firing rate to zero.

5. Calculate:
   Hit proportion = number of hits (2 above)/number of rounds (3 above).

6. Calculate:
   Hit rate = hit proportion (5 above) times firing rate (4 above).

(table continues)

Table A-1 (continued)

For each engagement:

7. Record opening time (lowest of the fire times). If no round is fired, code as missing or leave blank.

8. Record number of "C" and "I" classification errors.

   C - Classification error indicates that the crew failed to engage the more dangerous target first.

   I - Identification error indicates that the crew fired at a non-target.

   2-I - Indicates that the crew did <u>not</u> fire on a target.

   NOTE: There can only be one "C" error per engagement. Classification errors and identification errors will be grouped together in the performance records. Always check the number of targets presented, and which targets were fired upon to determine which errors were committed more than once. For example, for an engagement in which two targets were presented, and only one target was fired on, 4C-I represents 1-C, 2-I, and 1-I. In other words the crew engaged the less dangerous target first, failed to fire at the most dangerous target, and fired at a non-target.

9. Record number of D, L, M, R, and A system management errors.

   D - Indicates crew was exposed too long in hull defilade.

   L - Lasing error indicates that the crew failed to activate the LRF before the trigger pull. This is a true error only if the engagement is fired as a precision main gun engagement.

   M - Magnification error indicates that the gunner failed to switch to 10x before the trigger pull.

   R - Indicates that either the ammunition select switch setting or the GAS reticle did not match the ammunition fired.

   A - Ammo error indicates that the crew selected the wrong weapon or ammunition for the type of target presented. (For old programming, ignore these errors when SABOT is fired at helicopter targets.)

   NOTE: System management errors will be grouped together. For example, 2D-L means 1-D and 1-L, and 3D-L means 1-D and 2-L. Always check the type of error to determine which error is committed twice.

(<u>table continues</u>)

Table A-1 (continued)

For each engagement:

10. For each main gun round for which azimuth and elevation error information is available, calculate:

    Miss distance = Square Root (azimuth error^2 + elevation error^2).

    Information may be available for up to three rounds per target, with the information for the first two rounds on the shot pattern printout and the information for the last round on the situation monitor printout.

    Calculate the average miss distance for the engagement as the sum of the miss distances in the engagement divided by the number of rounds with miss distances. Record average miss distance (line 11a), total miss distance (line 11c), and the number of rounds with miss distances (line 11b).

    Do not use rounds fired in defilade in the calculation. These are rounds with very high (e.g. +/- 300 mils) elevation errors.

    If no rounds are fired in the engagement, code as missing or leave blank.

11. For engagement 4 in exercise 1, and engagement 5 in exercise 4, record friendly vehicle hits, either 0 or 1. For the remaining engagements, leave this column blank, or code as missing data.

Across all exercises:

12. Calculate overall firing rate as the weighted average of engagement firing rates, where each engagement is weighted by the number of targets in the engagement. That is, for each engagement multiply line 1 (number of targets) times line 4 (firing rate) and record in line 13. Sum the values in line 12 and divide by the number of targets (38 less the number of targets not scored because of dispersion).

13. Calculate overall hit probability:

    a. Calculate the weighted average of engagement hit percentages, where each engagement is weighted by the number of targets in the engagement. That is, for each engagement multiply line 1 (number of targets) times line 5 (hit proportion) and record in line 13. Sum the values in line 13 and divide by the number of targets.

    b. If one of the friendly targets is hit, multiple the calculated averages by 5/6. If both friendly targets are hit, multiple by 1/2.

(table continues)

Table A-1 (continued)

For each engagement:

14. Calculate hit rate as firing rate (12 above) times hit probability (13 above).

15. Calculate average the opening times as the sum of line 7 divided the number of engagements that are scored.

16. Average the number of C and I classification errors. Divided number of errors by the number of engagements scored.

17. Average the number of D, L, M, R, and A system management errors. Divided number of errors by the number of engagements scored.

18. Calculate the average miss distance by averaging the miss distances for each round for which the information is available. Sum 10b and divided by the sum of 10c.

Engagement Times

Exercise	*Engagement*	*Time*	*Exercise*	*Engagement*	*Time*
346331	All	30 sec	346220	1,4	35 sec
346110	1	35 sec	346220	2	50 sec
346110	2,3	45 sec	346220	3	45 sec
346110	4	40 sec	315631	1,2,4,6,10	30 sec
			315631	3,5,7,8,9	35 sec

Table A-2

Sample Situation Monitor (SM) Printout

Sec Act	Bearing/ Weapon	Tgt Type	Rounds 105mm	CX/C50	Projectile Impact Results/ Az	El	Errors
From Exercise 346220:							
A.	COAX	T72 WHOLE TROOPS	0	71	. . . .	. . . .	MISS - 25%
B.	SABOT	T72 WHOLE	2	0	R 3.96	D 0.00	MISS - 0
	SABOT	T72 WHOLE T72 WHOLE	1	0	L 0.34	D 0.01	KILL - 1
C.	SABOT	T72 WHOLE T72 WHOLE T72 WHOLE	1	0	R 0.36	D 0.02	KILL - 1
D.	SABOT	T72 WHOLE	1	0	L 0.81	U 0.65	MISS(D)-0
	SABOT	HIND-D	1	0	L 1.81	U 0.27	KILL - 1
From Exercise 315631:							
E.	SABOT	TRUCK	3	0	L 0.93	U 0.55	KILL - 1
F.	COAX	TRUCK	0	55	R 4.53	U 2.18	KILL - 10

The scoring procedure for firing rate (step four in Table A-1) indicates separate rules for three different cases depending on hits and the time information available from the printouts. Each engagement must be classified before it can be scored. Case "a" is engagements where all targets are hit. In our example, engagements E and F fall into this category. Each has one target and that target was hit. Case "b" is for engagements where at least one round is fired, at least one target is missed (including the possibility that all targets are missed), and the PA gives a time for the last round fired in the engagement. Sample engagements A and C fall into this category. For engagement A, only the troops were fired on and the PA shows a kill time of 18.8 seconds. For engagement C, only the first T-72 was fired on and the PA shows a opening time of 37.0 seconds for the one round fired. The third class, case "c," is engagements where at least one round is fired, at least one target is missed, but the PA does not give a time for the last round fired. Sample engagement B falls into this category. A total of three rounds were fired in engagement B, one hit on target 5 at 19.5 seconds, followed by two rounds fired on target 3. Because target 3 was not hit, only the first

Table A-3

Sample Performance Analysis (PA) Printout

	Target	Time ID	Time Fire	Time Kill	Ammo	Rounds 105mm	Rounds CX/C50	Hits %Cov	Errors Acq	Errors Sys Man
From Exercise 346220:										
A. 1	T72-W									
2	TROOPS	0.9	10.3	18.8	COAX	0	71	25%	3 C-I	1 D
B. 3	T72-W		31.9		APDS	2	0	0		
4	T72-W					0	0	0		
5	T72-W	10.7	18.2	19.5	APDS	1	0	1	2 I	1 L
C. 6	T72-W	18.5<	37.0	38.2	APDS	1	0	1		
7	T72-W					0	0	0		
8	T72-W					0	0	0	6 C-I	1 D
D. 9	T72-W		14.7		APDS	1	0	0		
10	HIND-D	7.4	22.2	23.3	APDS	1	0	1	0	1 D
From Exercise 315631:										
E. 6	TRUCK	3.5	11.6	25.8	APDS	3	0	1	0	2 A
F. 9	TRUCK	13.8	17.4	24.9	COAX	0	55	1	0	0

round fired at target 3 is given a time. No time is recorded for the second round fired on target 3. Finally, there may be engagements where no rounds are fired. We do not have an example of this case.

After classifying engagements by type, firing rate is calculated. Again, engagements E and F are case "a" engagements. For engagement E, three rounds were fired and the last round was a kill at 25.8 seconds (see Table A-3.) The third round is confirmed as the round with the kill time from the azimuth and elevation results (see Tables 10 and 12). The azimuth and elevation results for the first two rounds are on the shot pattern printout; the results for the third round appear on the situation monitor printout. The first two rounds are more than four mils off target center mass. The third round is within one mil of target center mass. We estimate the third round was fired at 24.8 seconds (one second less than the kill time). Therefore, the firing rate for engagement E is 3 divided by 24.8, or .12 rounds per second. For engagement F, the 55 COAX rounds are equated to 2 main gun rounds, and kill time was 24.9 seconds. Therefore, firing rate is 2 divided by 23.9, or .08 seconds per round.

Engagements A and C are examples of case "b" firing rate engagements. For these engagements, three different values must be calculated. The first, labeled value A, is the number of rounds fired divided by the time of the last round. For engagement A, that is 2 (equivalent rounds) divided by 17.8 (kill time minus one second), or .11 rounds per second. For engagement C, value A is 2 divided by 37.0 (the firing time), or .05 rounds

Table A-4

Sample Shot Pattern (SP) Printout

	No	Target	Ammo	Symbol	Round	Projectile Impact Azm	Elv
From Exercise 346220:							
B.	5	T72 WHOLE	APDS	1	1	-0.34	-0.01
	3	T72 WHOLE	APDS	2	1	+7.90	-478.26
	3	T72 WHOLE	APDS	3	2	+3.96	+0.00
C.	6	T72 WHOLE	APDS	4	1	+0.36	-0.02
D.	9	T72 WHOLE	APDS	5	1	-0.81	+0.65
	10	HIND-D	APDS	6	1	-1.81	+0.27
From Exercise 315631:							
E.	6	TRUCK	APDS	6	1	-4.04	+0.20
	6	TRUCK	APDS	7	2	-4.15	+0.48

per second. Value B is number of rounds time total time. Table A-1 gives the total time for each engagement in the test. For engagements A and C, the total times are 35 and 45 seconds, respectively. Thus, value B is 2 divided by 35 (or .06) for engagement A, and 2 divided 45 (.04) for engagement C. For Value C add one to the number of rounds, divide by total time. Value C is .09 for engagement A and .07 for engagement C. Now, these three values can be compared and a firing rate estimate selected. The rules for case "b" indicate that value A is selected as the estimate if it is smaller than C. For engagement C, A is less than C, and consequently, A is entered as the firing rate. For engagement A, value A is larger then value C. Following the rules for case "b" in Table A-1, value B becomes the firing rate estimate.

Finally, engagement B is a firing rate case "c." No time is available for the last round that was fired in the engagement. That is, the PA shows that three rounds were fired in the engagement. The "fire" column in the PA gives the time of the first round fired at each target in the engagement. In engagement B, the first round in the engagement, and the only round fired at target 5, was fired at 18.2 seconds. The second round in engagement was fired at target 3. Being the first round fired at target 3, a fire time is given, 31.9 seconds. The PA shows that a second round was fired at target 3, however, it was not a hit and no time is given for that round. Thus, the second round in the engagement is the last round with a time. This round is used as an initial estimate of firing rate. That is, for case "c," value A is the number of the last round with a

Table A-5

Scoring for Sample Exercises

Step	Description	Engagements A	B	C	D	E	F	Test Score
1	Number of targets	2	3	3	.	1	1	10[a]
2	Number of hits	.25	1	1	.	1	1	
3	Number of rounds	2	3	2	.	3	2	
4	Firing rate	.06	.07	.05	.	.12	.08	.07[b]
	Case a.	-	-	-	-	.12	.08	
	Case b. A	.11	-	.05	.	-	-	
	B	.06	-	.04	.	-	-	
	C	.09	-	.07	.	-	-	
	Case c. A	-	.06	-	.	-	-	
	B	-	.07	-	.	-	-	
	C	-	.09	-	.	-	-	
5	Hit proportion	.12	.33	.5	.	.33	.5	.36[b]
6	Hit rate	.01	.02	.02	.	.04	.04	.02[c]
7	Opening time	10.3	18.2	37.0	.	11.6	17.4	18.9[d]
8a	Classification error - C	1	0	1	.	0	0	.4[d]
8b	Classification error - I	0	0	1	.	0	0	.2[d]
8c	Classification error - 2I	1	1	2	.	0	0	.8[d]
9a	Exposure errors	1	0	1	.	0	0	.4[d]
9b	System management error - L	0	1	0	.	0	0	.2[d]
9c	System management error - M	0	0	0	.	0	0	0[d]
9d	System management error - R	0	0	0	.	0	0	0[d]
9e	System management error - A	0	0	0	.	2	0	.4[d]
10a	Average miss distance	.	2.15	36	.	3.10	.	2.33[e]
10b	Number of rounds with distances	.	2	1	.	3	.	.6[f]
10c	Total miss distance	.	4.30	.36	.	9.30	.	13.96[f]
11	Number of friendly vehicles hit	.	.	.	.	.	.	0[f]
12	Firing rate x no. of targets	.12	.21	.15	.	.12	.08	.68[f]
13	Hit prop x no. of targets	.24	1.0	1.5	.	.33	.5	3.57[f]

[a]Total number of hits.

[b]Average weighted by number of target in engagement, or average across targets.

[c]Average firing rate times average hit proportion.

[d]Unweighted engagement averages.

[e]Average weighted by number of rounds, or average across rounds with miss data available (sum or line 11c divided by sum of 11b).

[f]Total.

time, or 2 in the example, divided by the time for that round, 31.9. Thus,the value of A is .06 for engagement B. Values Band C for case "c" are calculated in the same manner as for case "b." For value B, it is 3 rounds divided by 45 second (.07), and for value C it is 4 rounds divided by 45 seconds (.09). Following the decision rule for case "c," value B is selected as the firing rate estimate because it is large than value A.

The fifth scoring step is to calculate hit proportion as number of hits (recorded in line 2 of the sample code sheet) divided by number of rounds fired (recorded in line 3). Hit proportion is entered in line 5 of the sample code sheet. Hit rate (line 6) is calculated by multiplying firing rate (line 4) times hit proportion (line 5).

The next several items are read from the U-COFT printouts. Opening time is the smallest fire time for each engagement. These are taken from the PA and recorded in the sample code sheet in line 7.

Classification and system management errors, steps 8 and 9, are coded on the PA. Item eight is subdivided into parts for recording classification errors. These are indicated as a "D" under the system management error column on the PA printout. Engagements A, C, and D all have such errors. Engagement D is not being scored. For the other two engagements with "D" errors, a 1 is entered on line 7. For the engagements without exposure errors, a 0 is entered on line 7. There are three kinds of classification errors: one coded as "C," one coded as "I," and one coded as "2-I." The PA gives a number and a letter code. Interpreting the code requires some creative algebra along with examination of the pattern of results for the rounds fired in the engagement. For example, engagement A in Table A-3 is coded with a "3 C-I." There is one "C" error (the crew failed to engage the more dangerous target, the T72, first). That leaves "2-I," and a "2-I" indicates failing to fire on a target (again, the T72). Thus, there is 1 "C" error and 1 "2-I" error. For engagement 6, the code is "6 C-I." There is 1 "C" error, leaving "5-I". Two of the T72 are not fired on accounting for 2 times "2-I" or "4-I." That leaves 1 "I," indicating that the crew fired a round, other than the one at the first T72, at a non-target. Similar kinds of analysis may be needed for other combinations of classification and system management errors. Other examples are given in Table A-1.

Similarly, five types of system management errors are coded with a number and letter code (D, L, M, R, and A). Like the classification errors, the code must be decomposed to determine numbers of each kind of error. Table A-1 gives an example.

Step 10 is the calculation of average miss distance. The shot pattern printout (SP) is the primary source of information for calculating average miss distance. Azimuth and elevation errors for the first two main gun rounds fired on each target are presented on this printout. If more than two rounds are fired at a target, the situation monitor printout gives errors for the last round fired. Therefore, error information may be available for up to three rounds. For the example crew, miss distances are calculated for engagements B, C and E only. Engagements A and F use COAX, and engagement D is not being scored.

Three rounds were fired in engagement B. The extreme elevation error for round 1 (-478.26) indicates that it was fired from turret defilade. It will not be used in the calculation of average miss distance. To calculate the miss distance for the first round at target 5, square .34 (.1156) and square .01 (.0001), then add them together (.1157), and take the square

root (.34). For the second round at target 3, there is no elevation error, so the azimuth error (3.96) is the miss distance. Averaging these two miss distances gives the average miss distance for the engagement (2.15). Only one round was fired in engagement C; its miss distance is .36. For engagement E, there is only one target, but three rounds were fired at that target. Miss information is available for the first two rounds on the shot pattern printout and for information for the third round is on the situation monitor printout. Miss distances are 4.05, 4.18, and 1.08 for these three rounds. The average miss distance is 3.10. To facilitate later calculation of average miss distance for the whole test, the sum of the miss distance for each engagement and the number of rounds on which the engagement average is based are also recorded as lines 11b and 11c.

Step 11 is to score the number of friendly targets hits. This is only scored for the two engagements in the test that included such targets. Our sample engagements did not include either of these two engagements.

The final two lines in Table A-5, corresponding to steps 12 and 13, are for calculating test averages for firing rate and hit proportion. Test averages are to be calculated across targets rather than engagements. That is, in the calculation of test averages, engagement B, which has three targets, will count three times as much as engagement E, which has only one target. Steps 12 and 13 weight each engagements' firing rate (step 4) and hit proportion (step 5) by the number of targets in the engagement (step 1). That is, line 4 is multiplied by line 1 to give line 12, and line 5 is multiplied by line 1 to give line 13. To obtain overall firing rate, the engagement values for line 12 are summed (.68, in the last column of Table A-5) and divided by the total number of targets presented (10, in the last column of line 1). Firing rate for the example crew on the sample test items is .07. Overall hit probability is calculated in a similar manner. The values in line 13 are summed (3.57) and divided by the number of targets, giving an overall hit probability for the sample test of .36.

The last column gives scores for the test as a whole. The primary measure of overall proficiency is hit rate. Overall hit rate is calculated in step 14 as the product of overall firing rate times overall hit probability. Thus, multiplying .07 times .36 yields .02, the estimated hit rate for the example crew on the sample test.

Finally, steps 15, 16, and 17 are to calculate average opening times, classification errors and system management errors across engagements (*without weighting for the number of targets*). Miss distance average, step 18, is calculated across main gun rounds fired. These averages, also presented in the last column of Table A-5, are useful supplementary metrics of performance which supply some limited information about possible causes for poor performance.

Interpretation of U-COFT M1 Gunnery Scores

The scoring procedure presented in the previous section yields proficiency scores at the engagement level and for the test as a whole. The engagement level scores are intended for the analysis of performance consistency. The type of skill measured by the U-COFT test has some inherent inconsistency which is greatest for those at the lower levels of skill. Thus, any one engagement is not likely to be a good indicator of overall proficiency, and comparisons among crews may best be conducted at the overall level of performance on the test as a whole.

The selection of measures of gunnery proficiency was based on the following assumption about the essence of gunnery proficiency:

The goal of tank gunnery is to

- *hit as many targets as possible,*
- *with as few rounds as possible,*
- *in as short a time as possible,*
- *in order of threat magnitude, and*
- *without hitting friendly vehicles.*

This statement contains a number of facets making the derivation of a single measure of gunnery proficiency difficult. However, we have identified, through our analysis presented in the technical report, hit rate, adjusted for hitting friendly vehicles, as the most representative measure of overall gunnery proficiency. In addition, several other measures are recommended for supplementary analyses. These include firing rate, hit probability, average opening time, average miss distance, and average numbers of classification and system management errors.

Hit Rate

In its most straight forward calculation, hit rate is simply number of hits divided by elapsed time. Hit rate has long been accepted by the Armor community has a fundamental measure of tank gunnery performance. For example, scoring of points for Tank Table VIII is based on a sliding scale derived from number of hits and elapsed time. The scale "slides" in relation to expected threat capabilities. That is, points are assigned to various friendly hit rates by comparing friendly hit rates to expected threat hit rates by calculating a hit exchange ratio (HER) of friendly hits to threat hits. Given that expected threat capabilities are the same for all crews, friendly hit rate is the performance measure on Table VIII that differentiates crews. The Directorate of Training and Doctrine, ORSA Division, has recently applied a similar, though somewhat refined, conceptualization to the scoring of Tank Table XII.

In order to calculate hit exchange ratios for U-COFT, an expected threat hit rate for the kinds of engagements represented in the U-COFT test would be needed. Expected threat hit rate was not calculated, however. Until further investigation of how U-COFT levels of performance match

actual M1 tank performance, comparing U-COFT scores threat capabilities is premature. However, hit rate is the U-COFT measure most likely to rank order crew in the same way as M1 tank performance.

Hit rate however has some deficiencies. For example, it does not incorporate round usage, target order, or mistakenly hitting friendly targets. An adjustment has been suggested for reducing hit rate based on loss of platoon productivity when friendly targets are hit. Given that the idiosyncracies of U-COFT graphics confound identification of friendly vehicles, researchers may want to examine hit rate with and without the suggested adjustment.

The remaining U-COFT performance measures are included for either one of two reasons. One is to make up for deficiencies in hit rate as a summary measure of performance. These include hit probability and classification errors. The other is add more detailed information about performance in order to determine some of the causes of good and poor hit rate. These include firing rate, opening time, average miss distance, and system management errors.

Firing Rate and Hit Probability

Firing rate and hit probability are the two principal components of hit rate (i.e., hit rate equals firing rate times hit probability) and are calculated in U-COFT scoring in order to derive hit rate. In addition, hit probability is important because it is an indicator of round usage. That is, higher hit probability means fewer rounds used, other things being equal. For example, two crews can have equal hit rates, but the one with the higher hit probability is the one using fewer rounds to achieve that hit rate. As pointed out in the text of the report, it is difficult to maximize both firing rate and hit probability. By examining distributions of both in relation to hit rate, research can begin to study how crews tend to handle the trade-off between speed and accuracy.

Opening Time

Opening time is obviously a component of firing rate and thus, also hit rate. In contrast to other research, we have chosen not to give opening time special emphasis. The new defensive doctrine that tanks will stay up in hull defilade means that both in the defense and in the offense tanks are exposed for the battle. Obviously, it is important to get the first round out fast. However, if firing the first round exposes the tank's position, it may be more important to fire subsequent rounds fast. Therefore, in terms of overall performance opening time is given no more weight than time between rounds. Opening times should be recorded, however, for comparison to previous research using opening time as a performance variable.

Average Miss Distance

Given that crews taking the test receive a common set of U-COFT targets, average miss distance is essentially redundant with hit probability. On the other hand, average miss distance can be used for some detailed analyses. For example, miss distance can be used to differentiate crews with very few hits. Also, it can be used to study crews' performance strategies. That is, miss distance is really missed-named because it is measured in mils from the center mass of the target. Thus, there is a "allowable miss" that still results in a target hit. The distance allowable to achieve a hit on a close target is larger than for a distant target. Given that crews can trade-off speed and accuracy, closer target should be engaged faster than distant target with just enough accuracy to achieve a hit (D. W. Bessemer, personal communication, February, 1988). This suggests the need for further analysis of the target range and average miss distance relationship.

Average Number of Classification Errors

Engaging multiple targets in an inappropriate order is the most important of the errors indicated under classification errors. The other two, firing at a non-target, and not firing at a target are redundant with hit rate. Either of the latter two error directly affects hit rate. The inappropriate order error, however is useful can be used to supplement hit rate information.

Average Number of System Management Errors

Five errors are recorded under system management errors. One is being exposed too long in hull defilade during a defensive engagement. By a recent change in doctrine, this is no longer an error. The other errors, lasing error, magnification error, ammo select switch error, and ammo selection error, are errors that reduce hit probability, and are therefore reflected in hit rate. They may, however, point to some particular causes of low hit rates.

Combinations of the U-COFT Metrics

Although hit rate is to some extent deficient, at present there is not sufficient information about trade-offs concerning hitting the wrong target first or firing excessive rounds and overall proficiency in terms of our conceptual assumption about the essence of tank gunnery. For example, one could add a penalty for round usage but without some complex combat modeling, we do not know how much of a penalty. Therefore, we have simply chosen to refrain from making any recommendations about ways of combining any of the recommended U-COFT scores.